

# Biological Responses to Short-Term Maximal Exercise in Male Police Officers

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Ismail Dergaa<sup>1\*</sup>, Helmi Ben Saad<sup>2,3,4\*</sup> , Mohamed Romdhani<sup>1</sup> ,  
Amine Souissi<sup>1,5</sup>, Mohamed Saifeddin Fessi<sup>1</sup>, Narimen Yousfi<sup>5</sup> ,  
Tasnim Masmoudi<sup>6</sup>, Nizar Souissi<sup>1</sup>, Achraf Ammar<sup>7#</sup>,  
and Omar Hammouda<sup>7#</sup>

## Abstract

The specifics of short-term physical exercise are similar to the immediate reaction demands placed on police officers. Identifying the physiological predisposition to short-term high-intensity exercise in male law enforcement officers will assist in understanding their metabolism and make a significant contribution to a much more personal and individualized workout program. This will improve physical fitness of individual officers, improving their preparedness for such times of emergency. This cross-sectional study was conducted to investigate the responses of hematological (erythrocytes, hemoglobin, hematocrit, leucocytes, monocytes, neutrophils, lymphocytes), hormonal (testosterone, cortisol, melatonin), biochemical (glucose, uric-acid, lactate, creatine-phosphokinase) data to short-term maximal exercise in male police officers ( $n = 20$ ). Blood samples were collected before- and after- the running-based anaerobic sprint test (RAST), and biological values were corrected for fluid shifts. Data were mean  $\pm$  standard deviation of differences (= after minus before RAST). After the RAST, values of cortisol, lactate, neutrophils, lymphocytes, and monocytes increased significantly by  $7.01 \pm 37.36$  mmol/l,  $7.55 \pm 1.67$  mmol/l,  $0.17 \pm 0.26$   $10^3/\mu\text{l}$ ,  $0.61 \pm 0.28$   $10^3/\mu\text{l}$ , and  $0.10 \pm 0.13$   $10^3/\mu\text{l}$ , respectively. After the RAST, values of melatonin, uric-acid, creatine-phosphokinase, hemoglobin, and hematocrit decreased significantly by  $-13.24 \pm 4.60$  pg/ml,  $-13.28 \pm 14.35$   $\mu\text{mol/l}$ ,  $-10.23 \pm 10.13$  IU/l,  $-2.01 \pm 0.81$  g/dl, and  $-4.46 \pm 0.59\%$ , respectively. Biological data of male police officers were affected by sprint test. Understanding changes in biological data following short-term maximal exercise can further assist in a better understanding of anaerobic metabolism, which will be helpful to find available methods for coaches to quantify training loads.

## Keywords

hematological response, hormonal response, inflammatory response, military police, short-term exercise

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The military police physical training program has principles directed to specific enhancement to physical standards desirable for the demanding activities of this profession (da Silveira et al., 2014). Anaerobic metabolism of the individual play a vital role in efficiency of performance (Kindermann et al., 1982). Police officers are expected to perform physically challenging activities as part of their potentially hazardous career, while upholding their duties to protect the public and prevent crimes. At all times, police officers have to be on high alert in case of a dangerous and demanding scenario. Police officers need to perform to the best of their physical and mental abilities utilizing their reserve of anaerobic metabolism in such situations (Lentz et al., 2019; Vanhees et al.,

2005). The specifics of short-term physical exercise has many similarities to the instant reaction demands needed of police officers. It is generally known that both acute and chronic exercises constitute a powerful stimulus for the endocrine system, modifying the plasma concentration of many hormones, including melatonin, testosterone and cortisol (Miyazaki et al., 2001; Monteleone et al., 1992; Nimmo et al., 2013; Theron et al., 1984). Melatonin, an indolamine mainly produced by the pineal gland, not only regulates circadian rhythm, but also has antioxidant, anti-inflammatory, metabolic and immune-modulatory properties (Di Bella et al., 2013; Escames et al., 2012). It has been reported that plasma melatonin levels are affected by physical exercise (Miyazaki et al., 2001;



Monteleone et al., 1992; Theron et al., 1984). Testosterone is a key anabolic hormone with numerous physiological capabilities in the human body (Buresh et al., 2009). With regard to exercise, testosterone plays a key role in the strength and development of skeletal muscles, bones and erythrocytes (Buresh et al., 2009). Cortisol is a catabolic hormone secreted from the adrenal cortex in response to physical and psychological stress (Irandoost & Taheri, 2018). Metabolism is affected by cortisol's release as cortisol maintains the blood glucose levels during physical exercise; the mechanism involved refers to the increase of amino acid and lipid mobilization by skeletal muscle and adipose tissue (Galbo, 2001). Cortisol facilitates this process by stimulating the liver to create the enzymes involved in the gluconeogenesis and glycogenesis pathways, transforming the amino acids and glycerol into glucose and glycogen (Irandoost & Taheri, 2018). Testosterone and cortisol are sensitive to exercise (Budde et al., 2015; Budde et al., 2010). Some studies have reported that acute exercise induced alterations in serum sex steroid hormone concentrations. According to Kinderman et al. (1982), serum testosterone concentrations decreased after running on a treadmill using the Bruce protocol (Bruce, 1971) in physically active males. In contrast, repeated high-intensity exercise (consisting of 10 repetitions of 30 seconds sprinting at a target load of 150% of the maximal work capacity) increased serum total testosterone and free testosterone in healthy young males (Smith et al., 2013). Testosterone and cortisol concentrations were significantly increased in high school students after a session of high-intensity exercise (70–85% of maximal heart rate) (Budde et al., 2015; Budde et al., 2010). Following high-intensity maximal tasks, many biochemical data increased, including creatine phosphokinase (CPK), blood lactate and glucose, and uric-acid (Ammar, Chtourou, Hammouda, et al., 2015; Ammar, Chtourou, Trabelsi, et al., 2015; Ammar et al., 2018; Sousa et al., 2019; Yalcin et al., 2003). CPK is a well-known biomarker of muscle damage and may contribute to the fatigue process by increasing the myoplasmic

concentration of inorganic phosphate (Khaitin et al., 2021). The blood lactate and glucose concentrations are routinely used as indicators of the skeletal muscle energy metabolism during exercise, and are considered as useful indicators of recovery ability in athletes (Dergaa et al., 2021; Hammouda et al., 2012). Uric-acid is an end-product of the purines nucleotides cycle (Hooper et al., 2000). It is a powerful plasma antioxidant in vivo (Hooper et al., 2000) that could contribute to 35–60% of the total antioxidant capacity (Finaud et al., 2006; Johnson et al., 2009; Waring et al., 2003). During exercise tasks, the measurement of hematological data has several advantages. First, some hematological data, such as hematocrit, are mandatory to apply the correction for fluid shifts and control changes in hormonal and biochemical parameters (Alis et al., 2015; Van Beaumont, 1972). Secondly, the leucocytes are the major cellular mediators of inflammation. Finally, high-intensity maximal tasks induced several changes in hematological data (Wardyn et al., 2008). The latter are dependent on the type, intensity and duration of exercise (Ammar et al., 2017, 2018; Belviranli et al., 2017).

Previous studies have mainly focused on how the time of day affects short-term maximal performance in highly trained athletes, students or sedentary participants (Belviranli et al., 2017; Benloucif et al., 2008; Chtourou et al., 2015; Gabriel et al., 1992; Kindermann et al., 1982; Mastaloudis et al., 2001; Miyazaki et al., 2001; Monteleone et al., 1992; Smith et al., 2013; Sousa et al., 2019; Theron et al., 1984; Wayner et al., 1987; Yalcin et al., 2003). To the best of the authors' knowledge, no previous study had focused on the diurnal variation of short-term maximal performance or the biological data of police officers. For anaerobic pathway, persistent short-term high intensity efforts are required (Chtourou et al., 2018). Exploring the biological response (e.g., hormonal, biochemical, and hematological) to short-term maximal exercise in male police officers will aid in the understanding of the metabolic impact of such exercise in this specific population. The findings can be useful to improve police officers'

<sup>1</sup>National Observatory of Sport, Research Unit "Physical Activity, Sport and Health", Tunis, Tunisia

<sup>2</sup>Farhat HACHED Hospital, Research Laboratory "Heart Failure, LR12SP09", University of Sousse, Sousse, Tunisia

<sup>3</sup>Faculté de Médecine de Sousse, Laboratoire de Physiologie et Explorations Fonctionnelles, Université de Sousse, Sousse, Tunisie

<sup>4</sup>Department of Physiology and Functional Exploration, Farhat HACHED Hospital, University of Sousse, Sousse, Tunisia

<sup>5</sup>National Center of Medicine and Science in Sport (CNMSS), Research Laboratory "Sport Performance Optimization", Tunis, Tunisia

<sup>6</sup>Farhat HACHED Hospital, Forensic Medical Service, University of Sousse, Sousse, Tunisia

<sup>7</sup>Faculty of Medicine of Sfax, Research Laboratory "Molecular Bases of Human Pathology, LR19ES13", University of Sfax, Sfax, Tunisia

\*These authors contributed equally as first authors.

#These authors contributed equally as last authors.

#### Corresponding Author:

Pr. Helmi Ben Saad, Department of Physiology and Functional Exploration, Farhat HACHED Hospital, University of Sousse, Street Mohamed KAROUI, Sousse, 4000, Tunisia.  
Email: helmi.bensaad@rns.tn

training program (i.e., personalization), physical performance and readiness to emergency situations. Despite the similarity between short-term exercise and the daily activities of police officers, the physiological impact of such exercise in this specific population is still unknown.

This study aimed to examine the possible changes in hormonal [i.e., testosterone, cortisol, melatonin], biochemical [i.e., glucose, uric-acid, lactate, CPK], and hematological [i.e., erythrocytes, hemoglobin, hematocrit, leucocytes, monocytes, neutrophils, lymphocytes] data following a running anaerobic sprint test (RAST) in male police officers to ascertain the effectiveness of the same.

## Participants and Methods

### Study Design

This was a cross-sectional experimental study. The study protocol was in accordance with the Helsinki Declaration for conducting human experimentation and was approved by the ethical committee of Farhat HACHED Hospital, Sousse, Tunisia (approval number: FH20201002). All participants have signed an informed consent, after receiving a complete verbal description of the protocol.

**Sample Size.** The sample size was calculated according to the following equation (Serhier et al., 2020):  $N = (Z_{\alpha/2})^2 s^2 / \Delta^2$ ; where “s” is the standard-deviation (SD) obtained from a previous study (Mastaloudis et al., 2001), and “ $\Delta$ ” is the accuracy of estimated or how close to the true mean, “ $Z_{\alpha/2}$ ” is the normal deviate for two-tailed alternative hypothesis at a level of significance (equal to 2.58 for 1% level of significance). According to Mastoulidis et al. (2001), race trial plasma levels of uric-acid ( $\mu\text{mol/l}$ ) increased from  $289 \pm 14$  pre-race to  $338 \pm 20$  by post-race [ $n = 11$  athletes (8 males), mean age:  $45 \pm 3$  years]. In this case, “s” is equal to  $6.0 \mu\text{mol/l}$  and “ $\Delta$ ” is  $3.5 \mu\text{mol/l}$ . The estimated sample size gives a sample of 19 male police officers.

### Participants

To control confounding effects, participants were instructed to avoid strenuous exercise 1 week prior to the test session and importantly to refrain from exercise during the 48 hr preceding the test session. Additionally, none of the participants had any previous injury or cardiopulmonary disease and they did not ingest any medications (e.g., anti-inflammatory drugs) or dietary supplements (e.g., creatine, foods rich in antioxidants) 1 week prior- and during- the testing day. The participants were asked to abstain from caffeine and alcohol consumption prior to, and during the experimental sessions.

### Experimental Design

Following an initial familiarization session, participants performed RAST. Blood samples were conducted on two separate occasions (before and 30 min after exercise). Before test sessions, participants underwent an overnight fast and were only permitted to drink one glass of water (i.e., 15–20 cL) to avoid the potential confounding influence of post-prandial thermogenesis (Ammar et al., 2016). All sessions were performed indoor, at the same time of the day between 6.00 a.m. and 7.00 a.m. to minimize the effects of diurnal variation in the measured data (Dergaa et al., 2021). In addition, sessions were conducted far from the full moon to avoid the effect of circalunar variation on the measured biological data (Dergaa et al., 2019, 2021). All physical tests were performed in normothermia (Souissi et al., 2019) at a temperature of  $23 \pm 2^\circ\text{C}$  and a relative humidity of  $62 \pm 4\%$ . During the baseline week preceding the study, the participants were instructed to keep their usual bed and wake-time within a self-selected range of 8 hr of nocturnal sleep.

### Blood Sampling and Analysis

Blood samples were collected from median cubital vein of right forearm of each participant, after 5 min of rest on blood collection chair [with the use of vacutainer blood collection system and tubes (BD, USA)]. Four tubes of three ml each were collected every time and mixed immediately with eight inversions of the tubes. Order of drawing blood was as follow: one heparin tube (green top), two ethylene-diamine-tetra-acetic acid (EDTA) tubes (lavender top), and one fluoride tube (gray top). One EDTA tube was stored at  $2-8^\circ\text{C}$  for complete blood count analysis and the other three tubes were centrifuged at 2500 rpm for 15 min for extracting plasma. Then, plasma was separated in sterile tubes labelled with each participant's anonymous identification and type of anticoagulant used in primary tube, that is, EDTA, and Fluoride. The first aliquoted tube containing EDTA plasma from each participant was used to determine melatonin, cortisol, and testosterone levels by commercially available radioimmunoassay (RIA) kits (A68449 melatonin RIA, IM1841 cortisol RIA, and IM1087 testosterone RIA, Beckman Coulter Laboratories, USA). The procedure follows the basic principle of RIA. Extraction from each sample was done by evaporation of the solvent, followed by resuspension in zero calibrator. Then, plasma samples, the control, and calibrators were incubated in monoclonal antibody-coated tubes with tracer. After incubation, the liquid contents of the tube were aspirated and the bound radioactivity measured. A calibration curve was established and values were determined by interpolation from the standard curve. The second aliquoted tube containing

heparinized plasma from each participant was used to measure CPK at 340 nm using the international federation of clinical chemistry kinetic method, and uric-acid at 604 nm using the uricase endpoint method. The third aliquoted tube containing fluorinated plasma was used to measure glucose at 340 nm using the glucose hexokinase endpoint method (Roche Diagnostics, USA). The last uncentrifuged EDTA tube was used to determine the complete blood count by impedance technology for blood cell counting and cyanide-free optical detection for hemoglobin measurement (H18 LIGHT, SFRI, France). The total blood count values were reported as numbers/uL, that is, leucocytes, neutrophils, monocytes, lymphocytes, erythrocytes, and hemoglobin as g/dL. The performance criteria were similar to those provided by the manufacturer and clinical laboratory improvement amendments standards. The intra-assay and inter-assay coefficients of variation were 5.5% and 9.5% for melatonin; 4.05% and 6.7% for cortisol, 4.46% and 8.06% for testosterone, 1.55% and 4.65% for CPK, 1.76% and 2.8% for uric-acid, 0.94% and 1.3% for glucose, 3.5% and 5.4% for leucocytes, 4.6% and 6.1% for neutrophils, 3.9% and 8.4% for monocytes, 1.5% and 3.8% for lymphocytes, 2.1% and 6.5% for erythrocytes, and 1.5% and 2.5% for hemoglobin, respectively. To eliminate inter-assay variance, all samples were analyzed in duplicate in the same assay run, and mean value was used (Ammar et al., 2020; El Abed et al., 2019). All assays were performed in the same laboratory under stringent quality control.

In order to correct for fluid shifts and to control for changes in blood measures, the percentage change in plasma volume was calculated [ $\% \Delta PV = (100 / (100 - \text{Hematocrit}_{\text{before}})) \times (100 (\text{Hematocrit}_{\text{before}} - \text{Hematocrit}_{\text{after}}) / \text{Hematocrit}_{\text{after}})$ ] (Van Beaumont, 1972). All after exercise biomarkers were corrected using the following formulae:  $\text{corrected biomarker}_{\text{after}} = \text{uncorrected biomarker}_{\text{after}} \times (1 + \% \Delta PV)$  (Alis et al., 2015).

## RAST

The short-term maximal performance was assessed with the RAST. The latter consisted of 6 × 35-m maximal sprints interspersed by 10-second passive recovery periods. RAST is a valid and reliable tool for assessing short-term power and capacity (da Silveira et al., 2014). Each participant performed a 12 min warm-up (5 min of jogging and 7 min of active dynamic stretching), followed by some acceleration to 5 min of jogging. The peak-, average- and minimal- powers were determined (Zagatto et al., 2009).

## Data Analysis

Data distributions were evaluated using the one-sample Kolmogorov-Smirnov test. Data were expressed as mean ± SD (95% confidence interval). A non-parametric test

(Wilcoxon matched pairs test) was used to compare biological data (before- vs. after- RAST). Hedge unbiased “d” values were used for effect size measurement (Cohen, 1992). The magnitude of the “d” was interpreted as trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), and very large ( $\geq 2.0$ ) (Batterham, 2002). Statistical significance was set at  $p < .05$ . The SPSS statistical software package (version 18.0 for Windows; SPSS Inc. Chicago, Illinois, USA) was used to perform all statistical calculations;

## Results

Twenty male police officers were included in this study. The mean ± SD of the age, height, body mass, and body mass index were,  $26 \pm 2$  years,  $178 \pm 7$  cm,  $80 \pm 7$  kg, and  $25.4 \pm 2.2$  kg/m<sup>2</sup>. All participants were performing resistance and endurance training approximately five times/week. Their average weekly training volume was ~10 hr. The mean ± SD of the peak-, average-, and minimal- powers (in W), were,  $765 \pm 108$ ,  $646 \pm 73$ , and  $552 \pm 59$ , respectively.

### Uncorrected Biomarkers Values

Comparison between before- and after- RAST for biological responses were detailed in Table 1S (Appendix). Compared to before the RAST, all the selected biological data significantly increased after the RAST, except for melatonin concentration which significantly decreased.

### Corrected Biomarkers Values

Comparison between before- and after- RAST for the corrected biological responses were detailed in Tables 1–3. Compared to before the RAST, after the RAST:

- i) Melatonin concentration significantly decreased, cortisol concentration significantly increased, and testosterone concentration was unchanged. The magnitudes of “d” were small for cortisol, and very large for melatonin (Table 1).
- ii) CPK and uric-acid concentrations significantly decreased, lactate concentration was significantly increased, and glucose concentration was unchanged. The magnitudes of “d” were large for uric-acid and CPK, and very large for blood lactate (Table 2).
- iii) Hemoglobin and hematocrit values significantly decreased, neutrophils, lymphocytes and monocytes values were significantly increased, and leucocytes and erythrocytes were unchanged. The magnitudes of “d” were moderate for neutrophils and monocytes, and very large for lymphocytes, hemoglobin and hematocrit (Table 3).

**Table 1.** Hormonal Markers Response to the Running Anaerobic Sprint Test (RAST) (n = 20 Male Police Officers).

	Unit	Before RAST	After RAST (corrected values)	Difference	p-value	Hedge unbiased "d"
Melatonin	(pg/ml)	55.10 ± 5.49 (52.53 to 57.66)	41.86 ± 3.97 (40.00 to 43.72)	-13.24 ± 4.60 (-15.39 to -11.09)	.001	-2.709 <sup>c</sup>
Cortisol	(mmol/l)	252.85 ± 11.06 (247.68 to 258.02)	259.86 ± 33.65 (244.11 to 275.61)	7.01 ± 37.36 (-10.48 to 24.49)	.037	0.274 <sup>a</sup>
Testosterone	(mmol/l)	21.23 ± 1.85 (20.37 to 22.10)	19.89 ± 2.14 (18.89 to 20.90)	-1.34 ± 3.03 (-2.76 to 0.08)	.073	-0.657 <sup>b</sup>

Note. Data were mean ± standard deviation (95% confidence interval). Difference: After RAST minus before RAST. p-value: Wilcoxon Matched Pairs Test (Before RAST vs. After RAST). Magnitude of "d": <sup>a</sup>Small (0.2 to 0.6), <sup>b</sup>Moderate (0.6 to 1.2), <sup>c</sup>Very large ( $\geq 2.0$ ).

**Table 2.** Biochemical Markers Response to the Running Anaerobic Sprint Test (RAST) (*n* = 20 Male Police Officers).

	Unit	Before RAST	After RAST (corrected values)	Difference	p-value	Hedge unbiased "d"
Blood lactate	(mmol/l)	1.07 ± 0.14 (1.00 to 1.13)	8.61 ± 1.72 (7.81 to 9.42)	7.55 ± 1.67 (6.76 to 8.33)	.001	6.056 <sup>c</sup>
Blood glucose	(mmol/l)	4.07 ± 0.19 (3.98 to 4.16)	4.03 ± 0.19 (3.95 to 4.12)	-0.03 ± 0.25 (-0.15 to 0.08)	.455	-0.206 <sup>a</sup>
Uric acid	(μmol/l)	275.05 ± 7.93 (271.34 to 278.76)	261.77 ± 9.30 (257.42 to 266.12)	-13.28 ± 14.35 (-19.99 to -6.56)	.002	-1.506 <sup>b</sup>
CPK	(IU/l)	151.70 ± 7.71 (148.09 to 155.31)	141.47 ± 6.18 (138.58 to 144.36)	-10.23 ± 10.13 (-14.97 to -5.49)	.001	-1.345 <sup>b</sup>

Note. CPK: creatine phosphokinase.

Data were mean ± standard deviation (95% confidence interval). Difference: After RAST minus before RAST.

p-value: Wilcoxon Matched Pairs Test (Before RAST vs. After RAST).

Magnitude of "d": <sup>a</sup>Small (0.2 to 0.6), <sup>b</sup>Large (1.2 to 2.0), <sup>c</sup>Very large ( $\geq 2.0$ ).

**Table 3.** Hematological Markers Response to the Running Anaerobic Sprint Test (RAST) ( $n = 20$  male Police Officers).

	Unit	Before RAST	After RAST (corrected values)	Difference	p-value	Hedge unbiased "d"
Leucocytes	( $10^3/\mu\text{l}$ )	6.89 $\pm$ 0.56 (6.63 to 7.15)	7.17 $\pm$ 0.48 (6.95 to 7.39)	0.28 $\pm$ 0.75 (-0.07 to 0.63)	.145	0.526 <sup>a</sup>
Neutrophils	( $10^3/\mu\text{l}$ )	3.48 $\pm$ 0.21 (3.38 to 3.58)	3.65 $\pm$ 0.21 (3.55 to 3.75)	0.17 $\pm$ 0.26 (0.05 to 0.29)	.011	0.793 <sup>b</sup>
Lymphocytes	( $10^3/\mu\text{l}$ )	2.24 $\pm$ 0.19 (2.15 to 2.34)	2.86 $\pm$ 0.19 (2.77 to 2.95)	0.61 $\pm$ 0.28 (0.48 to 0.74)	.001	3.198 <sup>c</sup>
Monocytes	( $10^3/\mu\text{l}$ )	0.69 $\pm$ 0.12 (0.63 to 0.74)	0.79 $\pm$ 0.08 (0.76 to 0.83)	0.10 $\pm$ 0.13 (0.04 to 0.17)	.005	0.961 <sup>b</sup>
Erythrocytes	( $10^6/\mu\text{l}$ )	5.22 $\pm$ 0.25 (5.10 to 5.33)	5.15 $\pm$ 0.36 (4.98 to 5.32)	-0.07 $\pm$ 0.44 (-0.27 to 0.14)	.559	-0.221 <sup>a</sup>
Hemoglobin	(g/dl)	15.60 $\pm$ 0.55 (15.35 to 15.86)	13.59 $\pm$ 0.59 (13.32 to 13.87)	-2.01 $\pm$ 0.81 (-2.39 to -1.63)	.001	-3.459 <sup>c</sup>
Hematocrit	(%)	44.79 $\pm$ 0.75 (44.44 to 45.14)	40.33 $\pm$ 1.25 (39.74 to 40.91)	-4.46 $\pm$ 0.59 (-4.74 to -4.18)	.001	-4.241 <sup>c</sup>

Note. Data were mean  $\pm$  standard deviation (95% confidence interval). Difference: After RAST minus before RAST. p-value: Wilcoxon Matched Pairs Test (Before RAST vs. After RAST). Magnitude of "d": <sup>a</sup>Small (0.2 to 0.6), <sup>b</sup>Moderate (0.6 to 1.2), <sup>c</sup>Very large ( $\geq 2.0$ ).

## Discussion

The main finding of this study including a cohort of 20 young male police officers was that the short-term maximal exercise significantly influenced hormonal (i.e., melatonin and cortisol), biochemical (i.e., lactate, uric-acid, and CPK), and hematological (i.e., neutrophils, lymphocytes, monocytes, hemoglobin, and hematocrit) data. To the best of the authors' knowledge, this the first study to investigate the hormonal, biochemical, and hematological response to short-term maximal exercise in male police officers.

### *Hormonal Responses to Short-Term Exercise*

After-exercise, melatonin decreased compared to the before-exercise level (Table 1). There is some controversy about the effects of exercise on the endogenous profile of melatonin secretion. It has been reported that melatonin levels increased (Theron et al., 1984), decreased (Monteleone et al., 1992) or remained unaffected (Miyazaki et al., 2001) by exercise in various studies (Escames et al., 2012). Such discrepancies could be due to differences in lighting conditions and the time of day at which the physical exercise was performed. Additionally, it is thought that the decreased level of melatonin could be caused by the circadian pattern of melatonin concentration. In fact, the circadian pattern of melatonin increases significantly at night, more significantly from 22h00. The secretion of melatonin persists for about 10 hr, with a peak (between 30 and 200 pg/ml) recorded around 02h00 (Benloucif et al., 2008). A plateau is observed up to 5 hr, after which the rate decreases rapidly to regain its basal diurnal level (Claustrat et al., 2005). In this study, the participants' usual wake time was 5.30 am, and the baseline blood test was conducted 30 min later with the second blood test being conducted around 30 min after RAST. We postulate that the decreased level of melatonin after the sprint test is an indicator of the drop of melatonin regaining its basal diurnal level and not to a response to the sprint test. Another explication of the decrease of melatonin after-exercise could be due to the use of melatonin as a powerful antioxidant to combat exercise-induced oxidative stress.

Concerning cortisol concentration, the findings highlighted an increase in its concentration following the RAST (Table 1). Accordingly, Kindermann et al. (1982) measured cortisol 50 min after aerobic exercise at the anaerobic threshold (i.e., 4 mmol/L of blood lactates) and "anaerobic" exercise (156% of maximal capacity) to exhaustion. The anaerobic exercise increased cortisol levels by 35%, with 12% of this increase occurring during the recovery period. There was a 54% increase observed after the aerobic exercise. Cortisol is a catabolic hormone secreted from the adrenal cortex in response to

physical and psychological stress (Chtourou et al., 2018). The increase of cortisol concentration following the RAST could be explained by the role of cortisol in regulating metabolism during the exercise (Sayyah et al., 2019). Cortisol helps maintaining the adequate blood glucose supply during physical exercise by increasing amino acid and lipid mobilization from skeletal muscle and adipose tissue (Galbo, 2001; Wolfe, 2001). Cortisol facilitates the mentioned process by stimulating the liver to create the enzymes involved in the gluconeogenesis and glycogenesis pathways permitting the catabolism of glycogen, amino acids and glycerol into glucose and by increasing catecholamine level, which contribute to greater carbohydrate use (Irlandoust & Taheri, 2018).

There was no statistical significant change in the testosterone level following the RAST (Table 1). This result is opposite to the one of Smith et al. (2013) who reported that high-intensity exercise (consisting of 10 repetitions of 30 seconds sprinting at a target load of 150% of the maximal work capacity) increased serum total and free testosterone in healthy young males. Some hypotheses were advanced to explain the elevation of plasma testosterone concentrations after physical exercise. The first is related to hemoconcentration (Kindermann et al., 1982). This hypothesis is retained in our study, since "uncorrected" values of after RAST testosterone was significantly higher by  $3.60 \pm 3.39$  mmol/l when compared to before RAST (Table 1S) and this difference disappeared when correction for fluid shifts was applied (Table 1). The second hypothesis is linked to the reduction in testosterone metabolic clearance resulting from decreased hepatic blood flow (Cadoux-Hudson et al., 1985). The third hypothesis is connected to the increase in gonadal secretion (Cumming et al., 1986). Finally, some studies have demonstrated that the sympathetic nervous system participates in elevating testicular secretion of testosterone during physical exercise (Fahrner & Hackney, 1998).

### *Biochemical Responses to Short-Term Exercise*

Concerning CPK, this study reported a large decrease in its concentration following the RAST compared to baseline (Table 2). This result is opposite to the one reported by Yalcin et al. (2003) who noted an increase in CPK values. During intense exercise, CPK passes into the interstitial medium and enters the bloodstream through the lymphatic system (Brancaccio et al., 2008). One possible explanation of the CPK increase reported by Yalcin et al. (2003) could be the characteristic of the RAST with its accelerations and decelerations leading to high eccentric bio-mechanical strain on the working muscles, which causes micro-injuries of the musculoskeletal system



(Russell et al., 2016). The change in CPK activity with regard to physical exercise depends on various factors (Brancaccio et al., 2008). Our results highlight the use of blood correction as a methodological factor influencing the magnitude and even the direction/sense of CPK responses. Indeed, without applying the blood fluid correction we reported a large increase in CPK concentration by 24.75 IU/L (Table 1S). When we have applied the blood fluid correction, the results has been inverted, and a significant decrease of CPK by  $-10.23$  IU/L was noted (Table 2). Since this is the first study who applied a correction for fluid shifts following RASTS, the authors failed to advance an explanation for the CPK decrease. Future studies should consider such methodological factor (i.e., blood fluid correction (Van Beaumont, 1972)) in order to have comparable results.

Likewise, lactate has a very large increase after-exercise compared to baseline values (Table 2). Similarly, previous studies revealed that lactate increased to values of 10–12 mmol/l at the end of a brief and intense exercise stint (Yalcin et al., 2003; Zagatto et al., 2009). From this intensity, the plasma concentration of lactate increases exponentially during an exercise with increasing load, to reach concentrations of 10 to 14 mmol/l, at maximum and supra-maximum intensities (Sousa et al., 2019). During exercise, muscle cells are responsible for increasing the plasma concentration of lactate. The production of lactate is proportional to the intensity of the exercise and directly linked to adenosine triphosphate demand.

Regarding uric-acid, this study reported a large decrease of this biomarker after the RAST compared to before (Table 2). Oppositely, Mastaloudis et al. (2001) reported that intense physical exercise increases uric-acid concentrations. Plasma uric-acid diffuses into muscles to protect them from free radicals (Hellsten et al., 1998). uric-acid in plasma or muscle is among the most important antioxidants thanks to its direct action on singlet oxygen, hypochlorous acid, the peroxy radical and peroxy nitrite or ozone (Hooper et al., 2000). Other studies have reported that uric-acid represents a significant part ( $>50\%$ ) of the antioxidant capacity in plasma (Wayner et al., 1987). In addition, uric-acid is involved in the protection of erythrocytes, cell membranes, hyaluronic acid, and deoxyribonucleic acid from free radical oxidation. This chemical feature may mean that physical exercise induced a high oxidative stress, which decreased the uric-acid concentrations (Wu et al., 2019).

Regarding glucose, no statistical significant change in this biomarker has been reported after RAST (Table 2). This result is opposite to the study of Sousa et al. (2019). The most likely cause of this stable after-exercise glucose is the increase in hepatic glycogen catabolism mediated by the effect of higher cortisol during the exercise.

## *Hematological Responses to Short-Term Exercise*

This study reported moderate to very large increases in neutrophils, lymphocytes, and monocytes data, very large decreases in hemoglobin and hematocrit data, and no changes in leucocytes and erythrocytes after the RAST (Table 3). Our findings are intermediate with those reported in the literature (Akerman et al., 2015; Belviranli et al., 2017; Gabriel et al., 1992; Yalcin et al., 2003). First, blood volume is one determinant of cardiorespiratory power and capacity (Akerman et al., 2015). Secondly, Belviranli et al. (2017) reported that hematocrit, hemoglobin, erythrocytes, leucocytes, and counts of the leucocytes subgroups increased after acute high-interval intermittent test and their values starting to trough toward resting levels about 3 hr after exercise and completely returned to resting levels in 6 hr. Yalcin et al. (2003) also detected a transient significant increment of erythrocytes and leucocytes after the short-term maximal performance test. A significant increase of leucocytes, lymphocytes, monocytes, and neutrophils has been noted after 60 seconds of exercise at 150% of maximal aerobic power (Gabriel et al., 1992). The authors believe that the most likely explanation of the inflammatory response to the RAST test (i.e., increase in neutrophils) is the “possible” muscle damage induced by the strenuous exercise. The nonexistence of change of leucocytes and erythrocytes concentration could be explained by the short duration of RAST test. Since we have corrected our biological data for fluid shifts, the hypothesis related to the decrease in plasma volume, which may increase the total blood count of the hematological data cannot be retained.

## *Study Strength and Limitations*

The correction of the after exercise biological data for fluid shifts and the control for changes in blood measures is considered as a strength point (Van Beaumont, 1972). In fact, during exercise plasma volume decreases acutely causing the well-known hemoconcentration effect (Harrison, 1985). The water flux from bloodstream is generally induced by the augmented osmotic pressure between blood vessels and extravascular space, as well as augmented hydrostatic pressure in capillaries (Harrison, 1985; Matomaki et al., 2018). This acute loss in plasma volume amplified the concentration of blood biomarkers irrespective of the probable responses from exercise (Matomaki et al., 2018). Hereafter, this phenomenon is vital to recognize when comparing biomarkers before and after an exercise bout (Alis et al., 2015; Matomaki et al., 2018; Van Beaumont, 1972). This is usually done by applying an equation of relative plasma volume change (Alis et al., 2015; Van Beaumont, 1972).

This study presents four main limitations. The first, and probably the most important, is the absence of a control group of athletes or inactive participants for examples. The validity of this study results cannot be completely linked to short-term maximal exercise. The second limitation concerns the non-use of a specific test to Police as a short-term maximal exercise. It is recommended that future studies use specific 'police test protocol' rather than test protocols related to sport performance to have more results that are distinct. The third limitation is related to the lack of a serial timed measurement point of the biomarkers during recovery. The latter methods allows accessing the kinetic of the biomarkers during the recovery process. Finally, our study only investigated acute response while the literature does not sufficiently support acute hormonal effects on longer-term changes. Our findings should be interpreted with caution and further longitudinal monitoring-based studies are warranted to better understand how acute physiological changes are translated to long-term performance change.

### Practical Recommendations

Identifying the physiological predisposition to short-term high intensity exercise in male law enforcement officers will assist in understanding their metabolism and make a significant contribution to a much more personal and individualized workout program. This will improve physical fitness of individual officers, improving their preparedness for such times of emergency. Understanding changes in biological data following short-term maximal exercise can further assist in a better understanding of anaerobic metabolism, which will be helpful to find available methods (valid and robust) for coaches to quantify training loads.

In conclusion, this study demonstrates that short-term maximal exercise influences hormonal, biochemical and hematological activities as demonstrated by the laboratory data measured. It has provided reasonable evidence to illustrate the effect of RAST on the biological data, as measured in this research. It is recommended for future studies to further explore the physiological responses to anaerobic exercise and its effects on the endocrine, hematological and biochemical data.

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### Authors' contributions

ID, HBS, AA, and OH: literature search, data collection, study design, analysis of data, manuscript preparation and review of manuscript.

MR, AS, MSF, NY, TM, and NS: literature search, study design, manuscript preparation and review of manuscript. All authors read and approved the final manuscript.

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### ORCID iDs

Helmi Ben Saad  <https://orcid.org/0000-0002-7477-2965>

MohamedRomdhani  <https://orcid.org/0000-0002-1715-1863>

Narimen Yousfi  <https://orcid.org/0000-0002-2507-0553>

### Supplemental Material

Supplemental material for this article is available online.

### References

- Akerman, A. P., Lucas, S. J. E., Baldi, C. J., Katare, R., & Cotter, J. D. (2015). Haematological adaptations to high intensity interval training (HIIT) in temperate and hot environments. *Extreme Physiology & Medicine*, 4(S1), A145–A145. <https://doi.org/10.1186/2046-7648-4-s1-a145>
- Alis, R., Sanchis-Gomar, F., Primo-Carrau, C., Lozano-Calve, S., Dipalo, M., Aloe, R., Blesa, J. R., Romagnoli, M., & Lippi, G. (2015). Hemoconcentration induced by exercise: Revisiting the Dill and Costill equation. *Journal of Sports Medicine and Physical Fitness*, 25(6), e630–637. <https://doi.org/10.1111/sms.12393>
- Ammar, A., Chtourou, H., Hammouda, O., Trabelsi, K., Chiboub, J., Turki, M., AbdelKarim, O., El Abed, K., Ben Ali, M., Hoekelmann, A., & Souissi, N. (2015). Acute and delayed responses of C-reactive protein, malondialdehyde and antioxidant markers after resistance training session in elite weightlifters: Effect of time of day. *Chronobiology International*, 32(9), 1211–1222. <https://doi.org/10.3109/07420528.2015.1079215>
- Ammar, A., Chtourou, H., Hammouda, O., Turki, M., Ayedi, F., Kallel, C., AbdelKarim, O., Hoekelmann, A., & Souissi, N. (2016). Relationship between biomarkers of muscle damage and redox status in response to a weightlifting training session: Effect of time-of-day. *Physiology International*, 103(2), 243–261. <https://doi.org/10.1556/036.103.2016.2.11>
- Ammar, A., Chtourou, H., & Souissi, N. (2017). Effect of time-of-day on biochemical markers in response to physical exercise. *Journal of Strength and Conditioning Research*, 31(1), 272–282. <https://doi.org/10.1519/JSC.0000000000001481>
- Ammar, A., Chtourou, H., Trabelsi, K., Padulo, J., Turki, M., El Abed, K., Hoekelmann, A., & Hakim, A. (2015). Temporal specificity of training: Intra-day effects on biochemical responses and Olympic-Weightlifting performances.

- Journal of Sports Science*, 33(4), 358–368. <https://doi.org/10.1080/02640414.2014.944559>
- Ammar, A., Chtourou, H., Turki, M., Hammouda, O., Chaari, A., Boudaya, M., Driss, T., Ayedi, F., & Souissi, N. (2018). Acute and delayed responses of steroidal hormones, blood lactate and biomarkers of muscle damage after a resistance training session: Time-of-day effects. *Journal of Sports Medicine and Physical Fitness*, 58(7-8), 980–989. <https://doi.org/10.23736/S0022-4707.17.07048-7>
- Ammar, A., Trabelsi, K., Boukhris, O., Glenn, J. M., Bott, N., Masmoudi, L., Hakim, A., Chtourou, H., Driss, T., Hoekelmann, A., & El Abed, K. (2020). Effects of aerobic-, anaerobic- and combined-based exercises on plasma oxidative stress biomarkers in healthy untrained young adults. *International Journal of Environmental Research and Public Health*, 17(7), 2601. <https://doi.org/10.3390/ijerph17072601>
- Batterham, A. M. (2002). Comment on probabilities of clinical or practical significance. *Sportscience*, 6. <https://doi.org/sportsci.org/jour/0201/amb.htm>
- Belviranli, M., Okudan, N., & Kabak, B. (2017). The effects of acute high-intensity interval training on hematological parameters in sedentary subjects. *Medical Sciences*, 5(3), 15. <https://doi.org/10.3390/medsci5030015>
- Benloucif, S., Burgess, H. J., Klerman, E. B., Lewy, A. J., Middleton, B., Murphy, P. J., Parry, B. L., & Revell, V. L. (2008). Measuring melatonin in humans. *Journal of Clinical Sleep Medicine*, 4(1), 66–69. <https://www.ncbi.nlm.nih.gov/pubmed/18350967>
- Brancaccio, P., Maffulli, N., Buonauro, R., & Limongelli, F. M. (2008). Serum enzyme monitoring in sports medicine. *Clinics in Sports Medicine*, 27(1), 1–18, vii. <https://doi.org/10.1016/j.csm.2007.09.005>
- Bruce, R. A. (1971). Exercise testing of patients with coronary heart disease: Principles and normal standards for evaluation. *Annals of Clinical Research*, 3(6), 323–332. <https://www.ncbi.nlm.nih.gov/pubmed/5156892>
- Budde, H., Machado, S., Ribeiro, P., & Wegner, M. (2015). The cortisol response to exercise in young adults. *Frontiers in Behavioral Neuroscience*, 9, 13. <https://doi.org/10.3389/fnbeh.2015.00013>
- Budde, H., Pietrassyk-Kendziorra, S., Bohm, S., & Voelcker-Rehage, C. (2010). Hormonal responses to physical and cognitive stress in a school setting. *Neuroscience Letters*, 474(3), 131–134. <https://doi.org/10.1016/j.neulet.2010.03.015>
- Buresh, R., Berg, K., & French, J. (2009). The effect of resistive exercise rest interval on hormonal response, strength, and hypertrophy with training. *Journal of Strength and Conditioning Research*, 23(1), 62–71. <https://doi.org/10.1519/JSC.0b013e318185f14a>
- Cadoux-Hudson, T. A., Few, J. D., & Imms, F. J. (1985). The effect of exercise on the production and clearance of testosterone in well trained young men. *European Journal of Applied Physiology*, 54(3), 321–325. <https://doi.org/10.1007/BF00426153>
- Chtourou, H., Ammar, A., Nikolaidis, P. T., Abdel Karim, O., Souissi, N., Chamari, K., & Chaouachi, A. (2015). Post-resistance training detraining: Time-of-day effects on training and testing outcomes. *Biological Rhythm Research*, 46(6), 897–907. <https://doi.org/10.1080/09291016.2015.1063204>
- Chtourou, H., Engel, F. A., Fakhfakh, H., Fakhfakh, H., Hammouda, O., Ammar, A., Trabelsi, K., Souissi, N., & Sperlich, B. (2018). Diurnal variation of short-term repetitive maximal performance and psychological variables in elite judo athletes. *Frontiers in Physiology*, 9, 1499. <https://doi.org/10.3389/fphys.2018.01499>
- Claustrat, B., Brun, J., & Chazot, G. (2005). The basic physiology and pathophysiology of melatonin. *Sleep Medicine Review*, 9(1), 11–24. <https://doi.org/10.1016/j.smr.2004.08.001>
- Cohen, J. (1992). Quantitative methods in psychology: A power primer. *Psychological Bulletin*, 112, 1155–1159.
- Cumming, D. C., Brunsting, L. A., 3rd, Strich, G., Ries, A. L., & Rebar, R. W. (1986). Reproductive hormone increases in response to acute exercise in men. *Medicine and Science in Sports and Exercise*, 18(4), 369–373. <https://www.ncbi.nlm.nih.gov/pubmed/2943968>
- da Silveira, C. L., de Souza, T. S., Batista, G. R., de Araujo, A. T., da Silva, J. C., de Sousa Mdo, S., Marta, C., & Garrido, N. D. (2014). Is long term creatine and glutamine supplementation effective in enhancing physical performance of military police officers? *Journal of Human Kinetics*, 43, 131–138. <https://doi.org/10.2478/hukin-2014-0098>
- Dergaa, I., Fessi, M. S., Chaabane, M., Souissi, N., & Hammouda, O. (2019). The effects of lunar cycle on the diurnal variations of short-term maximal performance, mood state, and perceived exertion. *Chronobiology International*, 36(9), 1249–1257. <https://doi.org/10.1080/07420528.2019.1637346>
- Dergaa, I., Romdhani, M., Fessi, M. S., Ben Saad, H., Varma, A., Ben Salem, A., Gadhavi, B., Chaabane, M., Souissi, N., & Hammouda, O. (2021). Does lunar cycle affect biological parameters in young healthy men? *Chronobiology International*, 38(6), 933–940. <https://doi.org/10.1080/07420528.2021.1897609>
- Dergaa, I., Varma, A., Musa, S., Chaabane, M., Ben Salem, A., & Fessi, M. S. (2021). Diurnal variation: Does it affect short-term maximal performance and biological parameters in police officers? *International Journal of Sport Studies for Health*, 3(2), e111424. <https://doi.org/10.5812/intjsh.111424>
- Di Bella, G., Mascia, F., Gualano, L., & Di Bella, L. (2013). Melatonin anticancer effects: Review. *International Journal of Molecular Sciences*, 14(2), 2410–2430. <https://doi.org/10.3390/ijms14022410>
- El Abed, K., Ammar, A., Boukhris, O., Trabelsi, K., Masmoudi, L., Bailey, S. J., Hakim, A., & Bragazzi, N. L. (2019). Independent and combined effects of all-out sprint and low-intensity continuous exercise on plasma oxidative stress biomarkers in trained judokas. *Frontiers in Physiology*, 10, 842. <https://doi.org/10.3389/fphys.2019.00842>
- Escames, G., Ozturk, G., Bano-Otalora, B., Pozo, M. J., Madrid, J. A., Reiter, R. J., Serrano, E., Concepcion, M., & Acuna-Castroviejo, D. (2012). Exercise and melatonin in humans: Reciprocal benefits. *Journal of Pineal Research*, 52(1), 1–11. <https://doi.org/10.1111/j.1600-079X.2011.00924.x>

- Fahrner, C. L., & Hackney, A. C. (1998). Effects of endurance exercise on free testosterone concentration and the binding affinity of sex hormone binding globulin (SHBG). *International Journal of Sports Medicine*, *19*(1), 12–15. <https://doi.org/10.1055/s-2007-971872>
- Finlaud, J., Lac, G., & Filaire, E. (2006). Oxidative stress : relationship with exercise and training. *Sports Medicine*, *36*(4), 327–358. <https://doi.org/10.2165/00007256-200636040-00004>
- Gabriel, H., Urhausen, A., & Kindermann, W. (1992). Mobilization of circulating leucocyte and lymphocyte subpopulations during and after short, anaerobic exercise. *European Journal of Applied Physiology*, *65*(2), 164–170. <https://doi.org/10.1007/BF00705075>
- Galbo, H. (2001). Influence of aging and exercise on endocrine function. *International Journal of Sport Nutrition and Exercise Metabolism*, *11*(Suppl), S49–S57. <https://doi.org/10.1123/ijnsnem.11.s1.s49>
- Hammouda, O., Chtourou, H., Chouachi, A., Chahed, H., Ferchichi, S., Kallel, C., Chamari, K., & Souissi, N. (2012). Effect of short-term maximal exercise on biochemical markers of muscle damage, total antioxidant status, and homocysteine levels in football players. *Asian Journal of Sports Medicine*, *3*(4), 239–246. <https://doi.org/10.5812/asjms.34544>
- Harrison, M. H. (1985). Effects on thermal stress and exercise on blood volume in humans. *Physiological Reviews*, *65*(1), 149–209. <https://doi.org/10.1152/physrev.1985.65.1.149>
- Hellsten, Y., Maclean, D., Radegran, G., Saltin, B., & Bangsbo, J. (1998). Adenosine concentrations in the interstitium of resting and contracting human skeletal muscle. *Circulation*, *98*(1), 6–8. <https://doi.org/10.1161/01.cir.98.1.6>
- Hooper, D. C., Scott, G. S., Zborek, A., Mikheeva, T., Kean, R. B., Koprowski, H., & Spitsin, S. V. (2000). Uric acid, a peroxynitrite scavenger, inhibits CNS inflammation, blood-CNS barrier permeability changes, and tissue damage in a mouse model of multiple sclerosis. *FASEB journal*, *14*(5), 691–698. <https://doi.org/10.1096/fasebj.14.5.691>
- Irandoost, K., & Taheri, M. (2018). Effect of a high intensity interval training (HIIT) on serotonin and cortisol levels in obese women with sleep disorders. *Women's Health Bulletin*, *6*(1), 1–5. <https://doi.org/10.5812/whb.83303>
- Johnson, R. J., Sautin, Y. Y., Oliver, W. J., Roncal, C., Mu, W., Gabriela Sanchez-Lozada, L., Rodriguez-Iturbe, B., Nakagawa, T., & Benner, S. A. (2009). Lessons from comparative physiology: Could uric acid represent a physiologic alarm signal gone awry in western society? *Journal of Comparative Physiology. B, Biochemical, Systemic, and Environmental Physiology*, *179*(1), 67–76. <https://doi.org/10.1007/s00360-008-0291-7>
- Khaitin, V., Bezuglov, E., Lazarev, A., Matveev, S., Ivanova, O., Maffulli, N., & Achkasov, E. (2021). Markers of muscle damage and strength performance in professional football (soccer) players during the competitive period. *Annals of Translational Medicine*, *9*(2), 113. <https://doi.org/10.21037/atm-20-2923>
- Kindermann, W., Schnabel, A., Schmitt, W. M., Biro, G., Cassens, J., & Weber, F. (1982). Catecholamines, growth hormone, cortisol, insulin, and sex hormones in anaerobic and aerobic exercise. *European Journal of Applied Physiology*, *49*(3), 389–399. <https://doi.org/10.1007/BF00441300>
- Lentz, L., Randall, J. R., Guptill, C. A., Gross, D. P., Senthilselvan, A., & Voaklander, D. (2019). The association between fitness test scores and musculoskeletal injury in police officers. *International Journal of Environmental Research and Public Health*, *16*(23). <https://doi.org/10.3390/ijerph16234667>
- Mastaloudis, A., Leonard, S. W., & Traber, M. G. (2001). Oxidative stress in athletes during extreme endurance exercise. *Free Radical Biology and Medicine*, *31*(7), 911–922. [https://doi.org/10.1016/s0891-5849\(01\)00667-0](https://doi.org/10.1016/s0891-5849(01)00667-0)
- Matomaki, P., Kainulainen, H., & Kyrolainen, H. (2018). Corrected whole blood biomarkers - the equation of Dill and Costill revisited. *Physiological Reports*, *6*(12), e13749. <https://doi.org/10.14814/phy2.13749>
- Miyazaki, T., Hashimoto, S., Masubuchi, S., Honma, S., & Honma, K. I. (2001). Phase-advance shifts of human circadian pacemaker are accelerated by daytime physical exercise. *American Journal of Physiology: Regulatory, Integrative and Comparative Physiology*, *281*(1), R197–205. <https://doi.org/10.1152/ajpregu.2001.281.1.R197>
- Monteleone, P., Maj, M., Beinart, L., Natale, M., & Kemali, D. (1992). Blunting by chronic phosphatidylserine administration of the stress-induced activation of the hypothalamo-pituitary-adrenal axis in healthy men. *European Journal of Clinical Pharmacology*, *42*(4), 385–388. <https://doi.org/10.1007/BF00280123>
- Nimmo, M. A., Leggate, M., Viana, J. L., & King, J. A. (2013). The effect of physical activity on mediators of inflammation. *Diabetes, Obesity & Metabolism*, *15*(Suppl 3), 51–60. <https://doi.org/10.1111/dom.12156>
- Russell, M., Sparkes, W., Northeast, J., Cook, C. J., Bracken, R. M., & Kilduff, L. P. (2016). Relationships between match activities and peak power output and Creatine Kinase responses to professional reserve team soccer match-play. *Human Movement Science*, *45*, 96–101. <https://doi.org/10.1016/j.humov.2015.11.011>
- Sayyah, M., Vakili, Z., Ehtram, H., Sarbandi, F., & Amooyi, Z. (2019). Effects of aerobic exercise on testosterone and cortisol hormone of blood serum of sedentary male students. *International Journal of Sport Studies for Health*, *2*(1), e87635. doi: 10.5812/intjssh.87635.
- Serhier, Z., Bendahhou, K., Ben Abdelaziz, A., & Bennani, M. O. (2020). Methodological sheet n degrees 1: How to calculate the size of a sample for an observational study? *La Tunisie medicale*, *98*(1), 1–7. <https://www.ncbi.nlm.nih.gov/pubmed/32395771>
- Smith, A. A., Toone, R., Peacock, O., Drawer, S., Stokes, K. A., & Cook, C. J. (2013). Dihydrotestosterone is elevated following sprint exercise in healthy young men. *Journal of Applied Physiology (1985)*, *114*(10), 1435–1440. <https://doi.org/10.1152/jappphysiol.01419.2012>
- Souissi, A., Yousfi, N., Dabboubi, R., Aloui, G., Haddad, M., & Souissi, N. (2019). Effect of acute melatonin administration on physiological response to prolonged exercise. *Biological Rhythm Research*, *51*(6), 980–987. <https://doi.org/10.1080/09291016.2019.1573462>

- Sousa, N. M. F. d., Silva Júnior, A. B. d., Mairink, R. d. S., Bertucci, D. R., Souza, M. V. C., & Martins, R. A. S. (2019). Determination of individual glucose threshold using pharmacy portable blood glucose meter. *Revista brasileira de medicina do esporte*, 25, 207–210.
- Theron, J. J., Oosthuizen, J. M., & Rautenbach, M. M. (1984). Effect of physical exercise on plasma melatonin levels in normal volunteers. *South African journal of sports medicine*, 66(22), 838–841. <https://www.ncbi.nlm.nih.gov/pubmed/6505888>
- Van Beaumont, W. (1972). Evaluation of hemoconcentration from hematocrit measurements. *Journal of Applied Physiology*, 32(5), 712–713. <https://doi.org/10.1152/jappl.1972.32.5.712>
- Vanhees, L., Lefevre, J., Philippaerts, R., Martens, M., Huygens, W., Troosters, T., & Beunen, G. (2005). How to assess physical activity? How to assess physical fitness? *European Journal of Cardiovascular Prevention and Rehabilitation*, 12(2), 102–114. <https://doi.org/10.1097/01.hjr.0000161551.73095.9c>
- Wardyn, G. G., Rennard, S. I., Brusnahan, S. K., McGuire, T. R., Carlson, M. L., Smith, L. M., McGranaghan, S., & Sharp, J. G. (2008). Effects of exercise on hematological parameters, circulating side population cells, and cytokines. *Experimental Hematology*, 36(2), 216–223. <https://doi.org/10.1016/j.exphem.2007.10.003>
- Waring, W. S., Convery, A., Mishra, V., Shenkin, A., Webb, D. J., & Maxwell, S. R. (2003). Uric acid reduces exercise-induced oxidative stress in healthy adults. *Clinical Science*, 105(4), 425–430. <https://doi.org/10.1042/CS20030149>
- Wayner, D. D., Burton, G. W., Ingold, K. U., Barclay, L. R., & Locke, S. J. (1987). The relative contributions of vitamin E, urate, ascorbate and proteins to the total peroxy radical-trapping antioxidant activity of human blood plasma. *Biochimica et biophysica acta*, 924(3), 408–419. [https://doi.org/10.1016/0304-4165\(87\)90155-3](https://doi.org/10.1016/0304-4165(87)90155-3)
- Wolfe, R. R. (2001). Control of muscle protein breakdown: Effects of activity and nutritional states. *International Journal of Sport Nutrition and Exercise Metabolism*, 11(Suppl), S164–S169. <https://doi.org/10.1123/ijsem.11.s1.s164>
- Wu, L., Sun, Z., Chen, A., Guo, X., & Wang, J. (2019). Effect of astaxanthin and exercise on antioxidant capacity of human body, blood lactic acid and blood uric acid metabolism. *Science & Sports*, 34(5), 348–352. <https://doi.org/10.1016/j.scispo.2018.12.008>
- Yalcin, O., Erman, A., Muratli, S., Bor-Kucukatay, M., & Baskurt, O. K. (2003). Time course of hemorheological alterations after heavy anaerobic exercise in untrained human subjects. *Journal of Applied Physiology*, 94(3), 997–1002. <https://doi.org/10.1152/jappphysiol.00368.2002>
- Zagatto, A. M., Beck, W. R., & Gobatto, C. A. (2009). Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. *Journal of Strength and Conditioning Research*, 23(6), 1820–1827. <https://doi.org/10.1519/JSC.0b013e3181b3df32>