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INFLUENCE OF CLIMATE AND NUTRITION ON THE PHYSICAL TRAINING OF NATIONAL LEVEL LONG-DISTANCE RUNNERS - CASE STUDY

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Abstract: Talking about athletes who train for long-distance running events, one cannot refer primarily to the aerobic system, which ensures the necessary energy support for a prolonged physical effort. This is a result of the oxidation process of food at a mitochondrial level. This is an observational and case study through which a practical analysis of the experience in the field is performed, respectively a monitoring of the trainings of the long-distance runners. The aim of this research was to improve the running time on the distance of 10000 m (progress recorded of 3 %, regardless of training conditions). Performance is investigated by considering the relationships between the various motor and functional parameters over the course of four weeks of training, based on the place of training, of climate and diet and weather. This research used as subjects four male professional athletes from the same club. Two of them (S1 and S2) took part in one month of training in Monte Gordo, Portugal at a temperature of 14 ± 2 ºC, while the other two (S3 and S4) performed the same type of training in Romania, at a temperature of 5 ± 2 ºC. The results have shown that heart rate, beat per minute, and average speed per kilometer, together with the climate and specific diet, have influenced the subjects' performance during the first competition they participated in after finishing this training stage.

Keywords: *climate, long-distance running, nutrition, track and field, training*

INTRODUCTION

The human body is exposed to various stress factors, but only a small number of them can be compared to the extreme stress that is caused by intense physical effort [1]. A simple example is the case of an individual with extremely high fever, close to lethal level, whose metabolism increases by approximately 100 %, compared to a marathon runner, whose metabolism during a race can increase by 2000 % of the normal value [1, 2]. Sports training generally depends on physical, technical, tactical, physiological and psychological factors [3]. Long-distance running training demands a high energy uptake [4, 5]. Athletes who train for such events are strong in all aspects: physical, mental, and emotional. All these qualities must be supported by a very well-trained cardiovascular and respiratory system [6, 7], to which must be added a metabolism that would help the athlete recover quickly [8, 9]. In the case of aerobic training, diet plays a crucial role during the recovery process. During the homeostatic recovery, a decisive part is played by carbohydrates and proteins [8, 10]. A solid nutritional plan is essential for achieving and maintaining an optimal athletic performance [11]. Diet is important for athletes, because it gives them the necessary energy to perform the required feats. The food they eat impacts their strength, performance, and recovery. Carbohydrates are essential for the diet of an athlete. During digestion, the carbohydrates are transformed into glucose, the primary source of energy for the body, this being also transformed into glycogen and stored in the liver and muscle tissue Glycogen is used as an energy source during training to fuel the muscles and other systems of the body. The athletes exercising intensely 60 to 90 minutes every day would need an increase in their energy received from carbohydrates to 60 - 70 %, compared to approximately 55 % of their normal uptake increase [12].

Proteins are also an important part of a training diet, playing a key role in the post-exercise recovery. The need for proteins is satisfied, generally, through a diet that is rich in carbohydrates, because many foods, especially those cereal based, are a combination of carbohydrates and proteins. The athletes should eat approximately two hours before exercising; their meal should be rich in carbohydrates, poor in fats, and should have a low or moderate amount of proteins. After exercising, the burned carbohydrates must be replaced, and the muscles recovered by including proteins in the meal after. The needed proportions of proteins and carbohydrates are varied, according to the intensity of their work and the type of sport [12]. Calcium is also perhaps the most important mineral for an athlete and must always be a part of their diet.

The evaluation of red cell count (RBC) can be useful for the monitoring of positive adaptations to training [13]. In addition, the testing of hemoglobin (HGB) and reticulocytes can be useful in the diagnosis of anemia, which can affect an athlete's performances. Persistent anomalies regarding red blood cells, hemoglobin, and hematologic markers can indicate also pathological conditions, such as deficiencies of iron, folic acid or vitamin B12 [14, 15]. The deficiency of iron, an essential component of hemoglobin, myoglobin, cytochromes, caused by sports, is frequently encountered in athletes [16]. The assessment of certain biochemical blood markers (red blood cells, white blood cells, serum) can reveal many things about the diet of an athlete [17, 18]. A low RBC or a low hemoglobin can help identify an iron deficiency [17, 18]. Elite athletes, who go through intense training, are often found to have anemia with iron deficiency. This can be solved through supplements.

The athletes have to react multiple times according to a series of internal perturbing factors, such as health, fatigue [19], work and recovery capacity, but also external factors, such as variations in the temperature sometimes during the same race, humidity and atmospheric pressure, UV rays [10]. Environmental high temperature can influence the cardiovascular regulation and body temperature, body fluid balance, and as a result, the aerobic performance [20]. Equally important is the constant monitoring of training effort and establishing its effectiveness. The quality of training is given by an optimal ratio between volume, intensity, and hardness [3].

Scientists are increasingly attracted to this type of ultra-endurance exercise, which is a model in the study of adaptive responses to extreme tasks and stress [21]. The most often mentioned parameters in literature to estimate a person's ability are speed and distance [22].

Starting from this data gathered from the literature, the main goal of this research was set: to investigate the relations between the various motor and functional parameters over the course of four weeks of training, performed under a varied climate. The second goal was to verify through the regression model which of the motor and functional parameters had a larger influence on the best results recorded during a 10000 m event. The supposition was that a training stage performed in January 2021 by long-distance runners under in a Mediterranean climate could have a bigger contribution to the improvement of cardiorespiratory fitness for long distances compared to a training stage performed in a temperate-continental climate.

This research was to investigate the relations between the various motor and functional parameters over the course of four weeks of training, performed under a varied climate. Also, was to verify through the regression model which of the motor and functional parameters had a larger influence on the best results recorded during a 10000 m event.

Starting from the literature data, the established objective was to improve performance recorded by 3 %, regardless of training conditions. Monitoring endurance athletes is difficult, there are few observational studies of this type with physiological monitoring of training.

MATERIALS AND METHODS

Subjects

This research used as subjects four male professional athletes from the same club of Bacau, Romania. They volunteered for this study, they informed of the aims of research, they understood the information and they signed an informed consent according to the guidelines of the Declaration of Helsinki. They will be henceforth called S1, S2, S3, and S4. All the four athletes have won medals at the Romanian National Championships. S1 holds the title of national champion for the 10000 m event U23, S2 is a marathon national champion (U23), S3 is the semi-marathon national vice-champion (U23), and S4 is the 800 m national vice-champion (U23).

Organization of the research

Considering the COVID-19 pandemic and the restrictions it brought, the athletes' training and the 2020-2021 competition system have suffered numerous modifications, delays, and relocations of the competitions, according to the level of infections, nationally and internationally. The period comprised in the study is one of the most important because it is a part of the athletes' second training stage of their competition year, being a time of quantitative accumulations. The training aimed primarily to increase the aerobic and mixed work capacity. For this, the literature recommends a work intensity of 74 - 84 % [3].

Each athlete has benefited from a physical training program, based on the goal they have set for themselves at the beginning of the year. Thus, S1 has trained to participate in the National Semi-marathon Championship, his goal being to set a personal record and win a medal with the senior team of the club, S2 and S3 have benefited from a physical training program to participate in the National Semi-marathon and marathon Championship, with the same goal - to win a medal with the senior team of the club and to set a personal record for that event, S4 has benefited from a physical training program to participate in the National U23 Championship, the 1500 m event, with the goal to win a medal with the senior team of the club and to set a personal record.

The athletes have performed their training according to their goals and according to their event, but in different environments. S1 and S2 performed a training stage in Monte Gordo, Portugal, between January 11, 2021, and February 7, 2021, while S3 and S4 worked using the same training plan in Bacau, Romania.

There were 11 training sessions per week, as follows: Monday, Tuesday, Wednesday, Friday, and Saturday - 2 sessions per day, Thursday - 1 session, and Sunday - resting day.

The difference in climate was favorable to the athletes who trained in Monte Gordo, Portugal, where the average temperature during the mentioned period was 14 ± 2 ºC, while in Romania, 5 ± 2 ºC.

In regards to the athletes' diet, it was made so it would satisfy, both for S1 and S2 (Portugal) and S3 and S4 (Romania) a series of demands, such as: to rebuild completely the body's energy loss, to comprise all basic nutritious substances (proteins, lipids, sugars, vitamins, mineral salts and water), to comprise foods with high nutritional value, easy to digest, with a pleasant aspect, taste and smell, in a sufficient quantity to satisfy their appetite.

Also, the meal timetable was followed strictly (3 - 3.5 hours before work and 45 - 60 min after work), calorie division on meals being 25 - 30 % for breakfast, 35 % for lunch, 5 - 7 % for the afternoon snack, before training, and 25 - 30 % for dinner. The menu contained foods such as eggs, cow cheese, vegetable soups or creams, beef, poultry, fish, rice, fresh fruit and vegetables, chocolate, all between 5000 - 6000 calories·day^{-1}, considering the animal-vegetable protein ratio or the animal-vegetable fat ratio. To quench their thirst, the subjects drank natural fruit juices (oranges, lemons, apples, tomatoes) and mineral water. To regulate their acid-base balance and prevent after-work acidosis, the subjects ate alkaline foods.

Body composition

The parameters body fat index (%), body mass index (%) and quantity of fat (kg) were calculated.

Performance verification

To verify the effectiveness of the training program, the authors chose to test the 10000 m running challenge, because it represents the competition event for three of the subjects and the verification challenge for S4. All runners have had the same verification conditions. The initial testing was conducted in Romania, before leaving for Portugal. The run was performed by all four athletes. The final testing was the results recorded by the four subjects during the first national championship of that year, in Timisoara, Romania, after returning from Portugal. It must be said that for the 10000 m event at the National Championships there is no qualifying norm. It was canceled because of the increasingly reduced number of runners in this event.

Monitoring of the training task

Smart technologies allowed constant monitoring of the athletes over the course of their work. The athletes wore during all training sessions Garmin Fenix 3Hr smart watches and Garmin belts, which eased the recording of the work volume, intensity, and hardness.
For each subject the authors recorded using the Garmin Fenix 3Hr smart watches and Garmin belts the distance covered (D), the duration of effort (DEf), average speed per kilometer (Vm/Km), average heart rate (HR AVG) and maximal heart rate (HRmax), average cadence (AVG cadence) and maximum cadence (Cadence MAX) over the course of the training sessions.

Hematological tests

To highlight the possible physiological changes at the beginning of the training stage and at the end of it, blood samples were taken at the medical tests' laboratory of the Regina Maria Clinic, in Bacau, which is a RENAR accredited center to perform blood tests, based on SR EN ISO 15189:2013. A complete blood count was performed, testing the hemoglobin (HGB), hematocrit (HCT), red cell count (RBC), white cell count (WBC), the eosinophils, the platelet count, the monocytes, basophils, neutrophils, lymphocytes, also highlighting the level of calcium and glucose. The blood tests were performed using the impedance hydro focusing method, the fluorescent flow cytometry, and SLS photometry, while the biochemical markers were highlighted using spectrophotometric methods, according to the standard regulations.

Statistical analysis

The recorded data was statistically analyzed with the SPSS 20 software. The Pearson coefficient was used to measure and describe the degree of correlation between the recorded values, analyzing the way in which the variables influence each other. The

authors validated the correlations where the Pearson coefficient values were closer to 1 and -1. A positive coefficient represented a direct proportionality between the analyzed values, while a negative one, an inversely proportional relation.
In order to verify which of the recorded parameters influences the most the time recorded during the 10000 m race, the regression and correlation analysis was done using the SPSS software.

RESULTS AND DISCUSSION

Presentation of the subjects

The subjects of this study were long-distance male runners, the main event being the 10000 m race.
In the first week of training session, S1 ran 131 km at an average speed of 4.23 min·km^{-1} and with an average HR max of 157 bpm. In the second week, he ran 167 km at an average speed of 4.02 min·km^{-1} and with an average HR max of 158 bpm. In the third week, he ran the same distance at an average speed 4.26 min·km^{-1} and with an average HR max of 148 bpm. S2 ran in the first week 143 km at an average speed of 4.07 min·km^{-1} and with an average HR max of 156 bpm. In the second week, he ran 195 km at an average speed of 4.32 min·km^{-1} and with an average HR max of 162 bpm. In the third week, he ran 201 km at an average speed 4.12 min·km^{-1} and with an average HR max of 149 bpm. In the third week, he ran 163 km at an average speed 4.10 min·km^{-1} and with an average HR max of 163 bpm. S3 ran in the first week 133 km at an average speed of 4.20 min·km^{-1} and with an average HR max of 159 bpm. In the second week, he ran 193 km at an average speed of 4.09 min·km^{-1} and with an average HR max of 143 bpm. In the third week, he ran 208 km at an average speed 4.39 min·km^{-1} and with an average HR max of 143 bpm. In the third week, he ran 199 km at an average speed 4.31 min·km^{-1} and with an average HR max of 142 bpm. S4 ran in the first week 122 km at an average speed of 4.35 min·km^{-1} and with an average HR max of 166 bpm. In the second week, he ran 121km at an average speed of 4.32 min·km^{-1} and with an average HR max of 166 bpm. In the third week, he ran 110 km at an average speed 4.32 min·km^{-1} and with an average HR max of 165 bpm. In the third week, he ran 121 km at an average speed 4.13 min·km^{-1} and with an average HR max of 165 bpm. Table 1 presents the body composition of the subjects.

Table 1. *Body composition of the subjects*

Subject	Body fat index [%]	Quantity of fat [Kg]	Net weight [Kg]
S1	13.2	7.9	51.7
S2	9.9	6.5	59.6
S3	12.9	10.2	63.3
S4	10.9	7.4	61.2

The body mass index (BMI) of S1, S2, S3, S4 are being within the reference values of 18.5 - 24.9 kg·m^{-2}. The quantity of fat was below the WHO reference values of 8.4 - 12.9 kg for S1, S2, S3 and S4 [23].
Table 2 presents the main biometrics characteristics of the subjects.

Table 2. *Biometrics characteristics of the subjects*

Subject	Age (years)	Height (cm)	Weight (kg)
S1	23	167	56
S2	25	170	60
S3	22	187	77
S4	25	176	60

Table 3 presents the total distance covered during the training stage, the average speed and the duration of effort, values recorded using the Garmin Fenix 3Hr smart watches and Garmin belts for each subject and analyzed using the Excel Office.

Table 3. *Total values of recorded parameters*

Subject	No. training sess.	Distance [km]	Average speed [min·km^{-1}]	HR Mean [bpm]	HR max [bpm]
S1	44	582.5	4.16	138	151.7
S2	44	702	4.15	148.9	157.5
S3	44	733	4.24	139.8	148
S4	44	474	4.28	150.6	165.5

The analysis of the distance covered in relation to the average speed and HR min and HR max shows that the goal of the training was achieved, in the sense that the work during that time had to be between 74 - 84 % [3] of the athletes' capabilities in order to increase their aerobic and mixed work capacity. Monitoring of the training task has presented on Figures 1 - 4. These figures present the main markers recorded during every training session (the distance covered by each athlete, the time per training session, the paces per minute, and the average heart rate per training session).

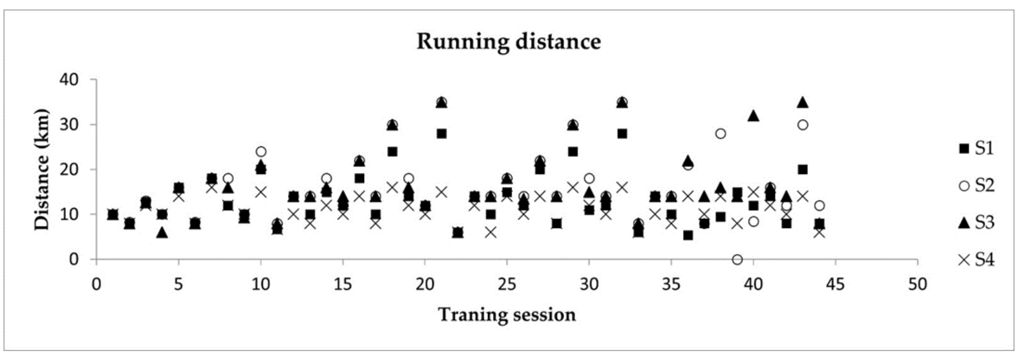


Figure 1. *Distance covered by each athlete*

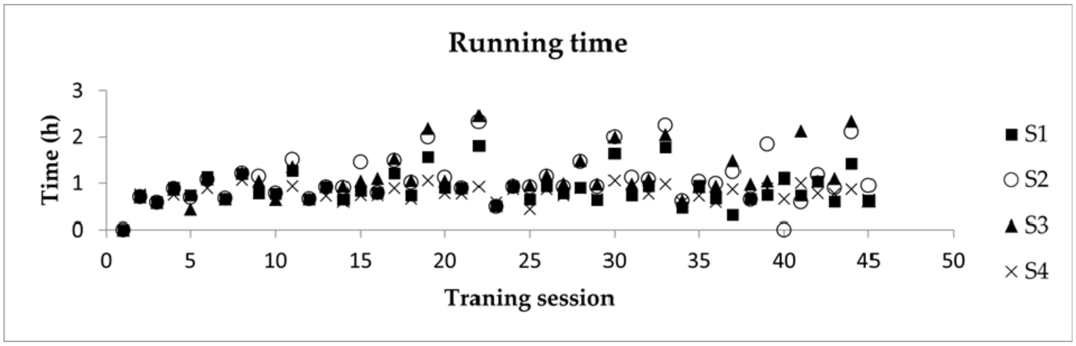


Figure 2. *Time per training session*

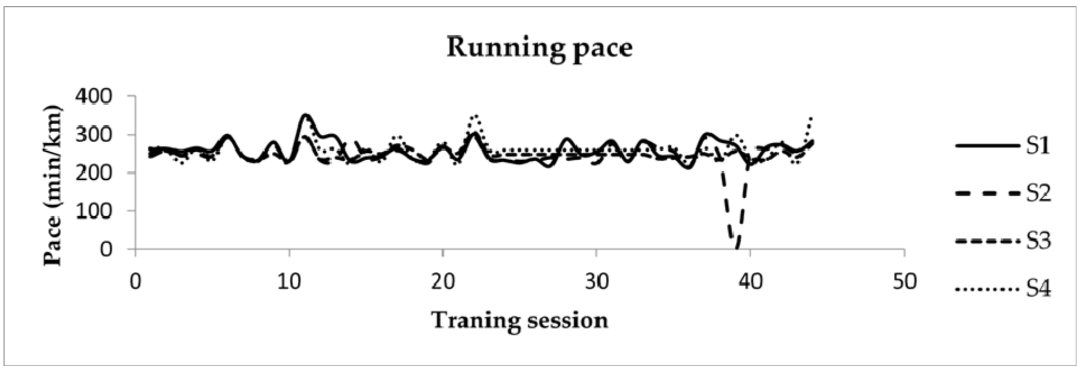


Figure 3. *Paces per minute*

Figure 4. *Average heart rate per training session*

The goal set for each athlete at the beginning of the competition year 2021/10000m was: S1 - 32.30.00 min, S2 - 33.20.00 min, S3 - 34.30.00 min, S4 - 33.30.00 min. Progress recorded as well as the initial and final performances of the subjects obtained during the 10000 m race are presented in Table 4.

Table 4. *The progress recorded after the training stage*

Subject	Initial test 10000 m [min]	Final test 10000 m [min]	Progress recorded	
			[min]	[%]
S1	33.17.00	32.21.52	1.4.52	3.23
S2	34.42.00	33.04.27	1.37.73	4.69
S3	35.08.00	34.25.16	1.17.16	3.66
S4	34.46.00	33.26.86	1.19.14	3.79

As one can see in Table 4, all four runners have achieved their time goals for the 10000 m event, setting personal records. So, the objective of research has been achieved.

Presentation and analysis of the data

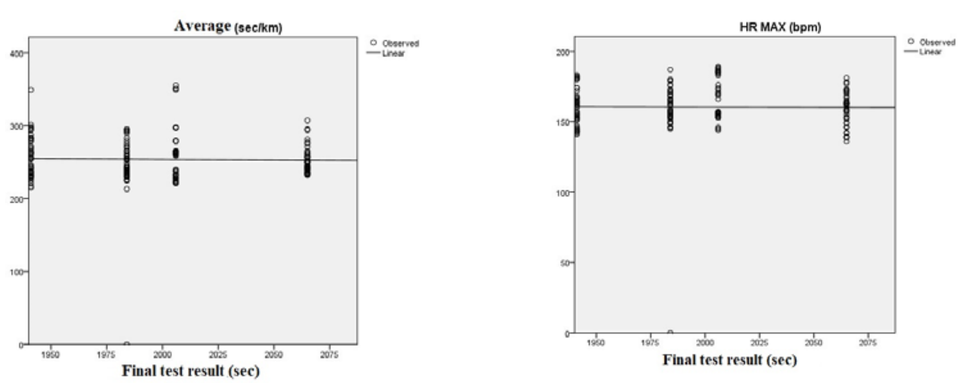
The functional variable of this study is represented by the initial and final values of the biochemical parameters, resulted from the blood tests and compared to the reference values. This data is presented comparatively for S1, S2, S3 and S4 (Table 5).

Table 5. *Biochemical values of subjects S1, S2, S3, S4*

Analyses	Reference values	S1		S2		S3		S4	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final
Red cell count (RBC)	4.44-5.61 mil·µL^{-1}	4.92	4.96	4.28	4.36	5.07	5.37	4.71	5
Serum calcium	8.5 – 10.0 mg·dL^{-1}	9.4	9.6	8.9	9.1	9	9.9	9.3	9.5
Serum glucose	74 – 106 mg·dL^{-1}	79.4	77.5	84.3	86.4	80	77	72.7	74.7

Out of all the recorded markers, the most important modifications can be observed in the red blood cells. The red blood cells' main function is to transport oxygen from lungs to tissues and to transfer CO2 from tissues to lungs. This is accomplished through the hemoglobin contained in the red blood cells. Their number has increased in all four subjects at the end of their training stage, because of their work. The regression model shows that the red blood cells and glucose levels have the highest share in sustaining the effort.

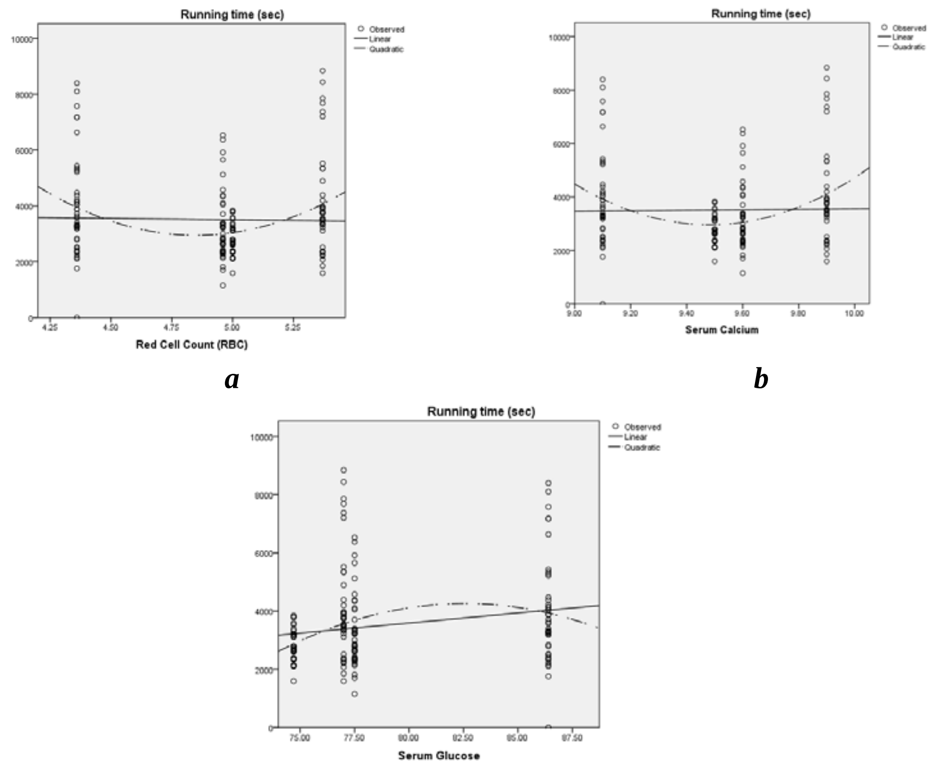
Figures 5a and 5b show the correlation between the recorded markers and the performance recorded by each athlete during the 10000 m race. The regression model was created for all markers, but the most significant correlations were recorded between the average speed and final time, and between the heart rate and the performance of each subject. It has an average correlation with the maximum heart rate (Pearson coefficient = 0.375, $p < 0.01$). The average speed has an average linear correlation with the cadence (Pearson coefficient = 0.447, $p < 0.01$). Heart rate has a very good correlation with cadence, the Pearson coefficient being 0.800, $p < 0.01$.



a ***b***

Figure 5. *The influence on the final result of (a) average speed;(b) heart rate*

Also, among the biochemical parameters tested, the regression model showed that red cell count (RBC), calcium and glucose had the highest weight in sustaining the effort (Figure 6 a, b, c).



a ***b***

c

Figure 6. *The influence on the final result of (a) red cell count; (b) calcium; (c) glucose*

The investigation of the relations between the various motor and functional parameters over the course of a 30-days training stage, performed under different climate conditions, has shown that the lowest links are found between the number of training sessions and the cadence, where the Pearson coefficient was 0.133, $p < 0.01$. Also, the number of training sessions has a weak correlation with the duration of work and heart rate.

The SPSS regression model regarding heart rate and performance shows that the best performances were recorded by S1 and S2, with an average heart rate (HR) of 147.36 bpm and HR max of 158.84 bpm, compared to S3 and S4 whose average HR was of 148.80 bpm and a HR max of 162.09 bpm, even though the average distance per training session was longer in the case of the first two subjects, 14559.91 m, compared to 13751.25 m. Also, subjects S1 and S2 have recorded a higher value in regard to average cadence, 93.76 paces$\cdot$min^{-1}, compared to S3 and S4 with 92.18 paces$\cdot$min^{-1}.

The authors believe that in the achievement of these higher results by S1 and S2 two main factors have contributed - climate and diet. The warmer climate of Portugal compared to the Romanian climate explains that part of the body energy was no longer used in the thermoregulation process [10], to this contributing also the Mediterranean-type diet.

CONCLUSION

The investigation of the relations between the various motor and functional parameters over the course of a 30-days training stage, performed under different climate conditions, has shown that the lowest links are found between the number of training sessions and the cadence, where the Pearson coefficient was 0.133, $p < 0.01$. Also, the number of training sessions has a weak correlation with the duration of work and heart rate.

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All authors had an equal contribution to the research.

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