Preliminary data on low peripheral blood oxygen levels induced by physical effort

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Abstract
Introduction: Since strength and endurance training has become very popular, we aimed to assess the possibility of hypoxemia determined in peripheral blood during exercise, starting from the hypothesis that a relatively large muscle mass would have a protective effect. Aim: Hypoxemia can cause serious illness and therefore we consider it useful to investigate the occurrence of this phenomenon during exercises of strength or endurance. Methods: The preliminary study was conducted on 8 subjects, both trained and untrained. With a Beurer pulse oximeter, heart rate and oxygen saturation of the capillary blood were measured before, during, and at the end of strength, or endurance or endurance combined with strength training. Results: The results have shown that hypoxemia occurs only under the conditions of high intensity training, which alternates endurance with strength exercises, simultaneously with decreasing heart rate, only in trained subjects and with relatively low muscle mass. Conclusions: The decrease in oxygen saturation in the peripheral blood occurs simultaneously with that of heart rate and it seems that large muscle mass has a protective effect on oxygen desaturation.

Key words: oxygenation, sports activities, muscle mass

Rezumat
Introducere: Deoarece antrenamentele de forță și durăranță au devenit foarte populare, ne-am propus aprecierea posibilității desaturării în oxigen a sângeului periferic în timpul efortului, plecând de la ipoteza că o masă musculară relativ mare ar avea un efect protectiv. Scop: Având în vedere că desaturarea în oxigen poate provoca afecțiuni grave, considerăm utilă investigarea apariției acestui fenomen în cursul exercițiilor de forță sau a celor de anduranță. Metode: Studiul preliminar a fost efectuat pe 8 subiecții, atât antrenați cât și neantrenați. Cu un pulsoximetrul Beurer s-au măsurat frecvența cardiacă și saturația în oxigen a sângeului capilar, înainte, în timpul și la sfârșitul unor șezunde de antrenament de forță, de anduranță sau combinate cu forță. Rezultate: Rezultatele au arătat că desaturarea în oxigen a sângeului periferic nu are loc decât în condițiile antrenamentelor de intensitate mare, ce alternază anduranța cu exercițiile de forță, simultan cu scăderea frecvenței cardiace, doar la subiecții antrenați și cu masă musculară relativ mică. Concluzii: Scăderea saturației în oxigen în sângele periferic are loc simultan cu frecvența cardiacă și se pare că masa musculară mare are un efect protectiv asupra desaturării în oxigen.

Cuvinte cheie: oxigenare, activități sportive, masă musculară

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Introduction
Research has shown that some healthy individuals undergoing walk tests exhibit a 4% decrease in peripheral blood oxygen levels, unrelated to age, gender, distance traveled or heart rate, but proportional to the body mass index [1]. Several studies [1] concluded that the use of hypoxemia levels for predicting respiratory anomalies may be erroneous.

Unlike untrained and moderately trained subjects, heavy trained endurance athletes may experience exercise-induced arterial hypoxemia [2], which is why future research is needed [3]. The way that ventilation/perfusion rate undergoes changes in distribution during intense exercise is not known [4].

Hypothesis
Since nitric oxide is synthesized in muscle fibers [5] and produces vasodilatation [6], we assume that one of the variables on which oxygen saturation levels depend during exercise is the degree of development of muscle mass.

Aim
Considering the popularity of practicing strength and endurance training (especially aerobics) by people of all ages and with different levels of training, we have proposed a preliminary study to assess whether hypoxemia occurs during these programs, and elucidating some of the factors that depend on it. Since low blood oxygen levels during intense physical activity may cause repeated episodes of hypoxic pulmonary vascular constriction and pulmonary hypertension [1], we consider the study to be important for the safety of leisure sports.

Methods
The research was conducted at the “New Power Gym” Sports Club in Iasi, in July 2017. With a Beurer pulse oximeter, heart rate (HR) and oxygen saturation of capillary blood (SpO₂) were measured in 8 subjects before, during, and at the end of an endurance training session, force session and both endurance combined with force. The programs were individualized and conducted under the supervision of coaches. The gender, age, anthropometric data, and training rate are included in Table 1. The intensity of the effort was consistent with the physical condition of each subject.

One of the authors (Hagiu Bogdan Alexandru) established the working protocol based on evidence in the literature and carried out the measurements. The other two have developed individualized strength-endurance programs.

Table I. Gender, age and anthropometric data of subjects participating in the study

| Subject | Gender | Age (years) | Height (cm) | Weight (kg) | Level of training |
|---------|--------|-------------|-------------|-------------|------------------|
| 1       | F      | 18          | 170         | 76          | trained          |
| 2       | F      | 28          | 165         | 52          | trained          |
| 3       | M      | 44          | 178         | 86          | trained          |
| 4       | M      | 47          | 178         | 86          | moderately trained |
| 5       | F      | 22          | 170         | 63          | untrained        |
| 6       | F      | 51          | 169         | 59          | untrained        |
| 7       | F      | 42          | 168         | 55          | trained          |
| 8       | F      | 35          | 160         | 55          | trained          |

Results
The results are included in Tables 2-9. The following tables contain the initial values of SpO₂ and HR (considered as those recorded before the start of the training program, or, by case, at the end of the warm-up) and the data measured during the breaks and at the end of training.
### Table II. Peripheral oxygen saturation levels and heart rate trends in subject 1

| Subject | Initial $\text{SpO}_2$ (beats/minute) | Initial HR (beats/minute) | Type of training | Duration (minutes) | Final $\text{SpO}_2$ | HR (beats/minute) |
|---------|--------------------------------------|---------------------------|------------------|--------------------|---------------------|------------------|
| 1       | 99<sup>1</sup>                       | 98<sup>1</sup>            | endurance        | 5                  | 98                  | 87               |
|         |                                      |                           | strength         | 15                 | 99                  | 121              |
|         |                                      |                           | endurance        | 15                 | 97                  | 107              |
| 2       | 98<sup>2</sup>                       | 108<sup>2</sup>           | endurance        | 15                 | 97                  | 167              |
|         |                                      |                           | alternating with strength | 8                  | 98                  | 137              |

<sup>1</sup>Values recorded at the beginning of the first training session (endurance, then strength), followed by endurance, after warming up; <sup>2</sup>values registered at the beginning of the second training session (endurance alternating with strength, then again endurance alternating with strength), after warming up.

### Table III. Peripheral oxygen saturation levels and heart rate trends in subject 2

| Subject | Initial $\text{SpO}_2$ (beats/minute) | Initial HR (beats/minute) | Type of training | Duration (minutes) | Final $\text{SpO}_2$ | HR (beats/minute) |
|---------|--------------------------------------|---------------------------|------------------|--------------------|---------------------|------------------|
| 2       | 97<sup>1</sup>                       | 90<sup>1</sup>            | strength         | 10                 | 98                  | 130              |
|         | 99<sup>2</sup>                       | 67<sup>2</sup>            | strength         | 20                 | 97                  | 134              |
|         | 99<sup>3</sup>                       | 75<sup>3</sup>            | endurance        | 10                 | 97                  | 147              |
|         |                                      |                           | alternating with strength | 15                 | 89                  | 83               |

<sup>1</sup>Values recorded after about 20 minutes of strength training; <sup>2</sup>values recorded after the break, the same training session; <sup>3</sup>values recorded at the start of a new training session (endurance alternating with strength).

### Table IV. Peripheral oxygen saturation levels and heart rate trends in subject 3

| Subject | Initial $\text{SpO}_2$ (beats/minute) | Initial HR (beats/minute) | Type of training | Duration (minutes) | Final $\text{SpO}_2$ | HR (beats/minute) |
|---------|--------------------------------------|---------------------------|------------------|--------------------|---------------------|------------------|
| 3       | 93<sup>1</sup>                       | 83<sup>1</sup>            | endurance        | 20                 | 97                  | 164              |
|         |                                      |                           | strength         | 10                 | 98                  | 133              |
|         | 96<sup>2</sup>                       | 96<sup>2</sup>            | endurance        | 15                 | 97<sup>3</sup>      | 140<sup>3</sup>  |
|         |                                      |                           | alternating with strength |                   |                     |                  |

<sup>1</sup>Values recorded at the beginning of the training session (endurance, then strength); <sup>2</sup>Values recorded after about 20 minutes of endurance + strength training; <sup>3</sup>Values recorded at the end of endurance alternating with strength training.

### Table V. Peripheral oxygen saturation levels and heart rate trends in subject 4

| Subject | Initial $\text{SpO}_2$ (beats/minute) | Initial HR (beats/minute) | Type of training | Duration (minutes) | Final $\text{SpO}_2$ | Final HR (beats/minute) |
|---------|--------------------------------------|---------------------------|------------------|--------------------|---------------------|------------------------|
| 4       | 99<sup>1</sup>                       | 82<sup>1</sup>            | endurance        | 40                 | 98                  | 111                   |
|         |                                      |                           | (cycloergometer, with intervals) |                     |                     |                        |

<sup>1</sup>Values recorded at the beginning of the training session.
**Table VI.** Peripheral oxygen saturation levels and heart rate trends in subject 5

| Subject 5 | Initial SpO₂ (beats/minute) | Initial HR (beats/minute) | Type of training | Duration (minutes) | Final SpO₂ (beats/minute) | HR (beats/minute) |
|-----------|----------------------------|--------------------------|------------------|-------------------|--------------------------|------------------|
|           |                            |                          | strength         | 25                | 98<sup>2</sup>            | 124<sup>2</sup>  |
|           |                            |                          | strength         | 15                | 98<sup>3</sup>            | 89<sup>3</sup>   |

<sup>1</sup> Values recorded after 10 minutes of endurance.
<sup>2</sup> Values recorded after the first session of strength training.
<sup>3</sup> Values recorded after the second session of strength training.

**Table VII.** Peripheral oxygen saturation levels and heart rate trends in subject 6

| Subject 6 | Initial SpO₂ (beats/minute) | Initial HR (beats/minute) | Type of training | Duration (minutes) | Final SpO₂ (beats/minute) | HR (beats/minute) |
|-----------|----------------------------|--------------------------|------------------|-------------------|--------------------------|------------------|
|           |                            |                          | endurance        | 25                | 98<sup>2</sup>            | 121<sup>2</sup>  |
|           |                            |                          | (cycloergometer) |                   |                          |                  |
|           |                            |                          | endurance        | 30                | 98<sup>3</sup>            | 112<sup>3</sup>  |
|           |                            |                          | (aerobic)        |                   |                          |                  |

<sup>1</sup> Values recorded at the beginning of the training session.
<sup>2</sup> Values recorded after first endurance training – cycloergometer.
<sup>3</sup> Values recorded after second endurance training – aerobic.

**Table VIII.** Peripheral oxygen saturation levels and heart rate trends in subject 7

| Subject 7 | Initial SpO₂ (beats/minute) | Initial HR (beats/minute) | Type of training | Duration (minutes) | Final SpO₂ Impact | HR (beats/minute) |
|-----------|----------------------------|--------------------------|------------------|-------------------|-------------------|------------------|
|           |                            |                          | endurance        | 3                 | 99                | 165              |
|           |                            |                          | strength         | 3                 | 99                | 131              |
|           |                            |                          | endurance        | 3                 | 99                | 179              |
|           |                            |                          | strength         | 3                 | 99                | 137              |
|           |                            |                          | endurance        | 2,5               | 98                | 172              |
|           |                            |                          | strength         | 2,5               | 98                | 136              |
|           |                            |                          | endurance        | 2,5               | 89                | 119              |
|           |                            |                          | strength         | 2,5               | 97                | 140              |
|           |                            |                          | endurance        | 1,5               | 98                | 171              |
|           |                            |                          | strength         | 1,5               | 98                | 143              |
|           |                            |                          | endurance        | 1,5               | 98                | 166              |
|           |                            |                          | strength         | 1,5               | 98                | 114              |

<sup>1</sup> Values recorded after warming up.

**Table IX.** Peripheral oxygen saturation levels and heart rate trends in subject 8

| Subject 8 | Initial SpO₂ (beats/minute) | Initial HR (beats/minute) | Type of training | Duration (minutes) | Final SpO₂ (beats/minute) | Final HR (beats/minute) |
|-----------|----------------------------|--------------------------|------------------|-------------------|--------------------------|------------------------|
|           |                            |                          | endurance        | 60                | 99                       | 144                    |

<sup>1</sup> Values recorded at the beginning of the training session.

**Discussions**

We observed a SpO₂ drop below 90 occurred in subjects 2 (8% versus baseline) and 7 (10% versus baseline), who underwent high intensity workouts. Subject 2 presented with hypoxemia after 25 minutes of exercise (89% SpO₂ after 15 minutes of endurance/force training versus 97% SpO₂ after 10 minutes of endurance). They correspond to a decrease of the heart rate (respectively 83, 147, 75 beats/minute). By comparison, even if subject 1 did only 23 minutes of alternative strength training with endurance, no degree of hypoxemia occurred even
after the heart rate started to drop (137 beats/minute and 98% SpO₂ after 23 minutes from the onset of effort, compared to 167 beats/minute and 97% SpO₂ after 15 minutes and 108 beats/minute with 98% SpO₂ at the beginning). In subject 7, desaturation (89% SpO₂) appeared after about 26 minutes from the onset of training, consisting of endurance/strength, simultaneously with a decrease in heart rate, then returned to the previous values. On the other hand, subject 3 did not suffer from hypoxemia, in spite of the fact that it went for 15 minutes through a similar exercise program with subjects 2 and 7, this after 30 minutes of endurance exercise combined with strength exercises. In subjects 2 and 7 desaturation occurred at a similar time interval with performance cyclists performing endurance exercise [7]. Subjects 2, 3 and 7 are trained and have performed high intensity training programs. The difference in reactivity can be attributed to the greater muscle mass of subject 3. The untrained subject 1, who performed an endurance/strength program, did not present hypoxemia. The cause can be high muscle mass or low effort level. It should be noted that in subject 8, desaturation did not occur after 60 minutes of aerobic training, so the duration of the effort is probably not a determining factor for lowering the partial oxygen pressure in the capillary blood.

Unlike previous studies that have found that hypoxemia occurs more easily in individuals with large body mass index [1], our results suggest that muscle mass has a protective effect. Although we did not establish body composition, the study subjects presented athletic figures. The results are in agreement with the fact that exercise-induced hypoxemia occurs predominantly in endurance athletes [2], which have a relatively small muscle mass than those who do strength training. In consensus with our results is a research that shows that in the elderly aerobic training improves cardiac parameters, but not SpO₂ levels [8]. The explanation is probably the progressive sarcopenia of the elderly, uncompensated during endurance training.

Conclusions

1. Under the conditions of dosed physical effort, performed under the supervision of the coach, it appears that hypoxemia occurs only under the conditions of high intensity training, which alternates the endurance with strength exercises, and only in trained subjects.
2. In this study, the decrease of blood oxygen levels occurs simultaneously with that of heart rate.
3. Preliminary data show that a relatively large muscle mass allows for a program of endurance exercises combined with strength exercises with no influence on blood oxygen levels.

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