

## The Influence of a Post-Exercise Slow Breathing Protocol on Heart Rate Recovery

تأثير بروتوكول تنفس بطيء بعد التمرين على استشفاء النبض القلبي

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### Abstract:

**Background and aim:** There is an established link between heart rate recovery values and breathing pace. The latter may lead to a faster heart rate recovery period. The objective of the present study was to investigate the influences of a post-exercise proposed breathing protocol on heart rate recovery.

**Methods:** 10 healthy amateur bodybuilders were selected through word of mouth to constitute the research sample. Once one of the participants is recruited, we demand from him to identify other potential participants (snowball sampling method).

The experimentation protocol was performed on an electronically braked cycle ergometer. Each participant attended the gym twice, separated by at least 48 h and no longer than seven days. In both testing sessions, the participants performed a 5 minutes warm-up. Then, they get three minutes of rest. Immediately after that, one of two 5-minute recovery protocols in a randomized order (between sessions A and B) is conducted. Either they followed the proposed slow breathing protocol, or they were instructed to breathe at a comfortable rate. Heart rate monitor polar H10 used for all heart rate measurements.

**Results:** The results revealed that the difference between the average (HRR) of the comfortable breathing recovery and the proposed breathing protocol at (p-value <0.05) was not significant.

**Conclusion:** Our results indicate that a breathing pace at 7.5 beats per minute did not enhance the average (HRR) after an All-out 60-second pedaling exercise.

**Keywords:** Heart rate recovery; Slow breathing; Hypocapnia; Hyperventilation.

### Introduction:

In sports, a quick recovery after exercise can be the profile of good physical condition (Watson et al., 2017). Therefore, an athlete recovers significantly faster after high-intensity exercise than a nonathlete. (Danieli et al., 2014), (Bunn et al., 2018). This enables the athletes to repeat intense physical effort after the shortest rest time possible. Heart rate recovery (HRR) is one of the major aspects of the athlete's recovery. It is defined as the physiological process of returning the heart rate (HR) to its resting state after a physical activity. (usually 1 to 5 minutes post-exercise). (Goldfarb et al., 2022). (HR) frequency draws a declining curve during the recovery phase until it reaches its baseline. It is named the resting heart rate (RHR). However, after an intense exercise, it would take up to 15 minutes or even more for the (HR) to return to its baseline (RHR). While the substantial changes in (HR) occur within the first minute of the recovery phase. This can be more remarkable in athletes.

The importance of (HRR) goes beyond solely being an overall cardio-pulmonary fitness indicator. It is worth mentioning that abnormal (HRR) is a powerful independent predictor of the risk of sudden death in asymptomatic men. (Jouven et al., 2005). And mortality. (Nishime., 2000). However, subjects with poor body composition are able to achieve significant improvements in their (HRR) through lifestyle intervention programs. Just a few months are sufficient for these improvements. (Carroll et al., 2012).

Previous studies have shown that (HRR) can be affected by various controllable and uncontrollable factors. Among the controllable factors are the ingestion of caffeine (Gonzaga et al., 2017) and smoking, which was associated with an attenuated (HRR) in both male and female smokers. However, this was significant only in females. (Papathanasiou et al., 2013). Besides that, the uncontrollable factors have more influence on (HRR). This was more explicit in the substantial longitudinal influence of age, which was negatively related to (HRR) irrespective of gender. Consequently, boys recover faster than men after a maximal intensity exercise (Guilkey et al., 2014). Moreover, it is negatively related to the body composition factors (Body mass index (BMI), Body fat percentage (BF %), and waist-to-hip ratio (WHR)) among males of all ages. (Ahmadian & Roshan, 2015; Ohuchi et al., 2000). Furthermore, (HRR) showed a significant correlation with  $\dot{V}O_{2max}$  (Watson et al., 2017) cardiorespiratory fitness (Facioli et al., 2021), and mean strength at the individual anaerobic lactic threshold. (Römer & Wolfarth, 2022). In addition to that (HRR) after one minute is also affected by exercise mode (Andić et al., 2016). It is faster after cycle ergometer exercise than the treadmill. (Maeder et al., 2008). This might be due to the bigger muscular-mass used during the treadmill exercise. Kaikkonen et al. (2008) concluded that (HRR) was lower after continuous intervention versus interval one with a similar workload. And it was significantly correlated with HRR at 10 and 30 seconds (Watson et al., 2017). Consequently, it is difficult for researchers to eliminate all of the random factors that may interfere with and influence the results of their scientific experiments.

Furthermore, (HRR) quick improvement is affected by the physical requirements of the sports discipline. Because types of sports showed unequal influence on (HRR)

enhancement, Some sports showed better results on (HRR) than others. For example regularly playing the badminton showed better results in (HRR) improvement than playing squash. (Obaid et al., 2022).

The respiratory system is another substantial factor that affects heart rate (HR) due to its physiological link to the cardiovascular system, and both rely on each other (Schüttler et al., 2020). Hyperventilation or hypoventilation are the mechanisms of the respiratory system which is able to change both the amount of CO<sub>2</sub> (Rodney & George, 2003) and O<sub>2</sub> in the body fluids.

The hyperventilation results in a decrease in the arterial Pco<sub>2</sub> (respiratory alkalosis). (Jonathan, 2020). This abnormal respiratory alkalosis process causes an excessive loss of CO<sub>2</sub>. The latter results in a fall in blood [H<sub>2</sub>CO<sub>3</sub>] and [H<sup>+</sup>]. Thus, (pH rises) (Rodney & George, 2003). The latter would cause partial respiratory compensation, especially after an anaerobic lactic exercise. ( Hall & Hall, 2021) while hypoventilation causes respiratory acidosis, which generally understood as the opposite of respiratory alkalosis.

Hyperventilation cannot increase the amount of O<sub>2</sub> in the blood significantly. For instance, hemoglobin would become slightly more saturated (97 to 98%). If PAO<sub>2</sub> were to rise from 100 to 120 mm Hg. (Rodney & George, 2003). Some previous studies have found that hyperventilation can affect (HR) in general and post-exercise (HRR). Besides that, voluntary hypocapnia hyperventilation lowers heart rate during the exercise and post-exercise recovery. However, with repeated exercise bouts, this effect is mitigated . (Dobashi et al., 2017)

Sakamoto et al. (2014) and Barth et al. (2017) concluded that hyperventilation during inter-set recovery mitigates the decrement in performance over a repeated bouts of high-intensity intermittent training. These results demonstrate that this technique was more effective in later high-intensity exercise bouts. These were associated with a substantial metabolic acidosis. Thus, the maintenance of the intensity of physical effort for an extended period of time. Leithäuser et al. (2016) have also concluded that a voluntary hypocapnic hyperventilation can enhance 30 seconds Wingate anaerobic test (WAnT) cycling sprint performance, and the results were comparable to what was resulted after efficient bicarbonate ingestion.

Several studies proved that the respiratory system influences the overall performance. Thus, it seems logical that voluntary hyperventilation or hypoventilation may have an influence on the heart rate recovery (HRR), especially when it comes to intermittent high-intensity exercise (repeated bouts). Therefore, the study aimed to examine the effectiveness of post-exercise slow-breathing proposed protocol on enhancing (HRR).

We hypothesized that a post-exercise breathing pace at (7.5 breaths per minute) would increase (HRR).

## **1. Materials and Methods:**

### **1.1 Participants:**

The sample of the study comprises ten healthy amateur bodybuilders from Algeria, who were selected through word of mouth to constitute the research participants. Once one of the participants is recruited, he is asked to identify other potential participants using a snowball sampling method. All the participants have the following criteria: 1) male, 2) Aged

between 18 and 30 years, and 3) neither a smoker nor a drug addict. 4) none of the participants was exposed to any supplements, nor were they medically diagnosed with heart problems previously. The descriptive data of the subjects are in Table 1.

**Table 1. Descriptive data of the participants.**

| Variables                                | Mean $\pm$ (SD) |
|------------------------------------------|-----------------|
| Body mass (Kg)                           | 67.3 $\pm$ 7.8  |
| Height (M)                               | 1.76 $\pm$ 0.04 |
| BMI.                                     | 21.7 $\pm$ 2.1  |
| Age (Years).                             | 23.2 $\pm$ 4.3  |
| Months of Training.                      | 4 $\pm$ 1.6     |
| Training Frequency. (sessions per week). | 4 $\pm$ 0.8     |
| RHR (bpm).                               | 66.1 $\pm$ 5.3  |
| HR max (bpm).                            | 191.8 $\pm$ 3   |

Data are shown as Mean  $\pm$  SD; SD = Standard Deviation; BMI= Body mass index; RHR = resting heart rate; bpm = beats per minute; HR max = Age-predicted maximum heart rate.

The age-predicted maximum heart rate was calculated using the Tanaka formula  $208 - 0.7 \times \text{age}$  (Tanaka et al., 2001).

### 1.2. Experimental procedure:

#### 1.2.1 Before testing:

The experiment took place in a gym, each participant attended two times, separated by at least 48 hours and no longer than seven days. They were asked to avoid the consumption of coffee, tea, energy drinks, or any other stimulants or supplements 6 hours preceding both testing sessions. In addition, the participants were instructed to avoid intense physical activity 48 hours before testing, to eat light meals, and to keep well hydrated for 2 hours before both sessions.

Before the first testing session. All participants were familiarised with the exercise test equipment and the testing procedures. For the equipment, we used ergo-cycle, the heart rate monitor, the slow-breathing pace proposed protocol. The latter was conducted through the following a video that shows the lungs filling in and emptying following a metronome beep. Then, the participants filled out an information form containing personal, health, and training information.

The experimentation protocol was conducted on an electronically braked cycle ergometer (technogym recline excite 700ie touch screen version). Before the warm-up, the

participant adjusted the sitting position so that his knee angle was about 5 degrees when his foot reached the farthest paddling point. And throughout the test, he was wearing a Polar H10 chest-strap heart rate monitor after moisturizing its electrodes as mentioned in the manual guide, which was used for all heart rate measurements. And a (Decathlon Newfeel scale) was used for all weight measurements.

#### 1.2.2 Measurements:

All measurements and tests were conducted during evening hours, in the same place, and under constant conditions of temperature (between 18°C and 19°C) and humidity (between 35% and 40%), except for height, weight, and resting heart rate (RHR) measurements that were taken during morning hours. Concerning resting heart rate (RHR) measurements, they were obtained at a baseline with the subjects in a sitting-position, after two minutes of rest. If eligible, the participants conducted the testing process in the evening. All participants with high (RHR) (higher than 80 bpm) were excluded from the study. Heart rate recovery (HRR) determined as the average (HR) during the 5-minute recovery phase calculated by the Polar Beat App.

#### 1.2.3 Polar H10 chest-strap sensor validation:

The polar H10 chest strap monitor proved to be one of the most accurate heart rate assessing monitors (Vermunicht., 2023). Schaffarczyk et al. (2022) concluded that the Linear heart rate variability measured by the Polar H10 heart rate monitor closely matches with a reference electrocardiogram (ECG) measurements in terms of RR intervals and heart rate (HR).

#### 1.2.4 Warm-up.

In both testing sessions, the participants performed a warm-up protocol with 5 minutes of pedaling on the cycle ergometer at a cadence of 60 revolutions per minute (RPM), following a metronome beep with level 6 of resistance (the equivalent to 90 Watts generated at 60(RPM)), at the 2nd, 3rd and 4th minutes of the warm-up the participants performed a 5 seconds sprint at the same resistance level.

#### 1.2.5 3-minutes rest:

Once the 5 min warm-up completed, the participants rested for 3 minutes by sitting on the cycle ergometer.

#### 1.2.6 60-Secondes All-out.

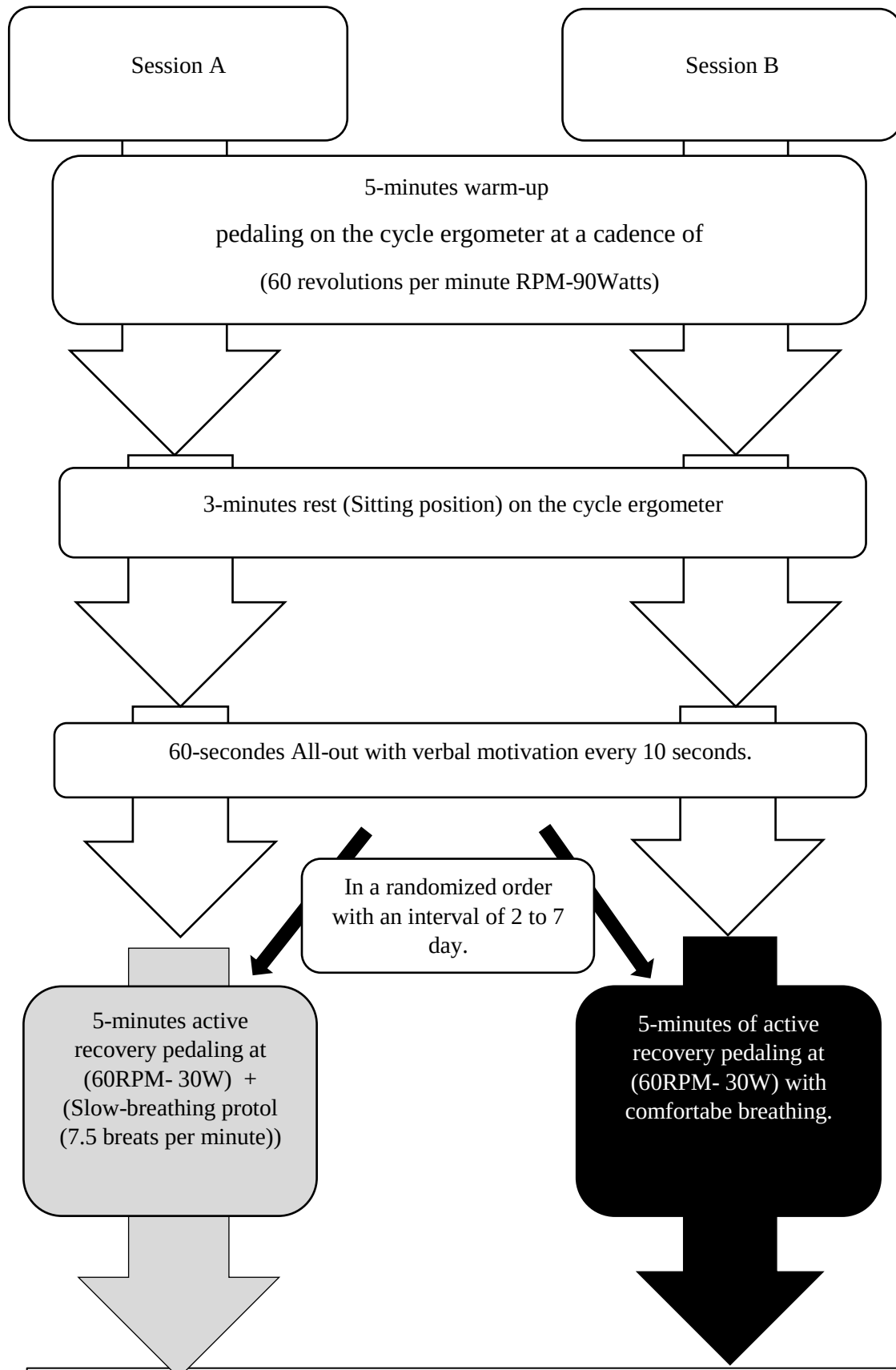
The participants executed a 60-second all-out pedaling at the 13th resistance level (the equivalent to 190 Watts generated at 60 (RPM)). They were verbally motivated every 10 seconds by the same examiner.

#### 1.2.7 Recovery phase:

Immediately after the 60 seconds All-out, one of two 5-minute recovery protocols in a randomized order is conducted. Either they followed the proposed slow-breathing pace protocol, or they breathed at a comfortable rate. During both recovery protocols, the participants pedaled following a metronome beep with level 1 of resistance (the equivalent to 30Watts generated at 60 (RPM)). However, In the proposed breathing protocol, the participants were following the breathing pace of 4 seconds of inhalation followed by 4 seconds of exhalation with a total of 8 seconds for each breathing cycle (7.5 breaths per

minute) with the help of a video that shows lungs filling in and emptying displayed on a phone screen in front of them. The following diagram presents the experimentation protocol.

**Figure.1. Diagram of the experimentation protocol.**



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## 2. Statistical analysis :

All data were analyzed using the Statistical Package for Social Sciences software (SPSS 26 version, Chicago, IL). Standard deviation (mean  $\pm$  SD) was used to measure the dispersion of the descriptive data of the participants. While Shapiro-Wilk test was used to confirm the normality of the data in both comfortable breathing (avg HRR) and slow-breathing protocol (avg HRR)

**Table 2. Test of normality (Shapiro-Wilk).**

|                                   | Statistic | df | Sig. |
|-----------------------------------|-----------|----|------|
| Comfortable breathing (avg HRR)   | .947      | 10 | .633 |
| Slow-breathing protocol-(avg HRR) | .925      | 10 | .399 |

Concerning the statistical differences in (HRR) variable between comfortable breathing (avg HRR) and breathing protocol (avg HRR) we used the Wilcoxon Signed Ranks Test. Statistical significance set at p-value <0.05.

**Table 3. Wilcoxon Signed Ranks Test results.**

|                        | Bre pro - Com bre   |
|------------------------|---------------------|
| Z                      | -1.207 <sup>a</sup> |
| Asymp. Sig. (2-tailed) | .228                |

a: Based on negative ranks.

Bre pro: Breathing protocol (avg HRR)

Com bre: Comfortable Breathing (avg HRR)

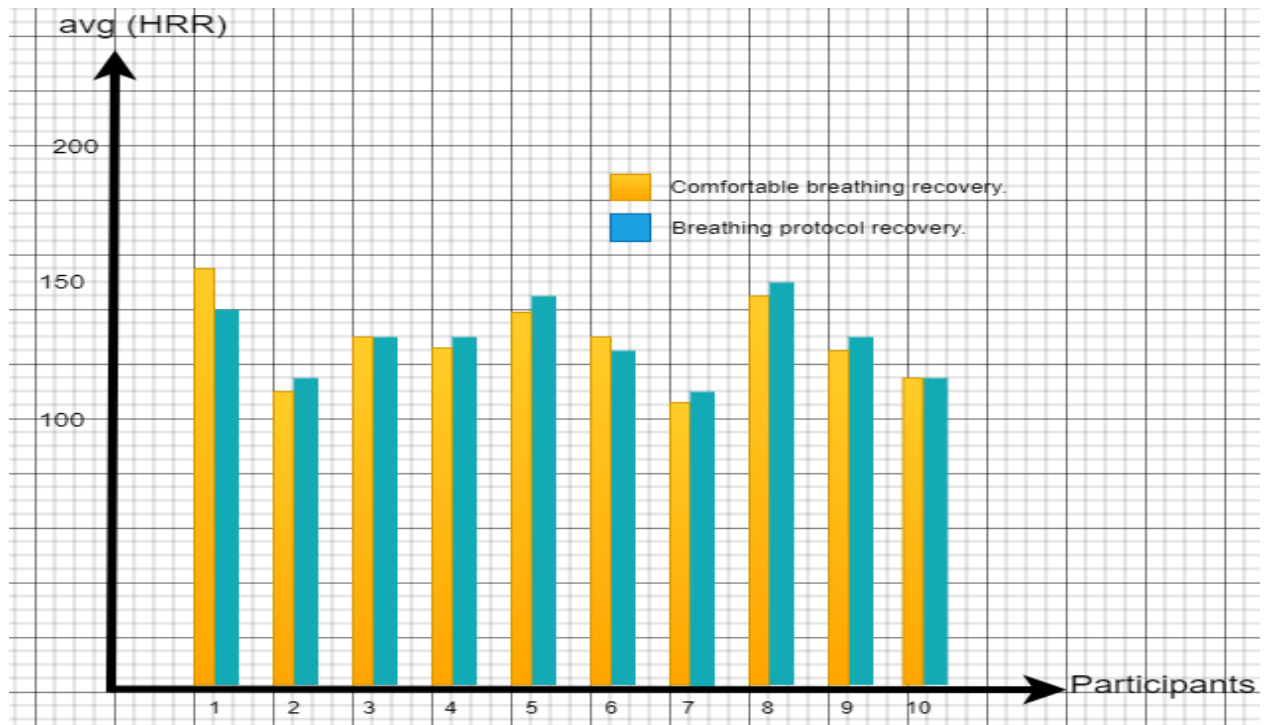
## 3. Results:

The results revealed that the difference between the average (HRR) of the comfortable breathing recovery and the proposed breathing protocol at (p-value <0.05) was not significant.

While six out of ten participants had higher average heart rate recovery (HRR) when following the proposed slow-breathing protocol breathing. Two participants had the same average (HRR) values, and the other two showed lower average heart rate recovery (HRR)

when following the proposed slow-breathing protocol than when comfortably breathing. Data are presented in Figure 2

**Figure.2. Average (HRR) comparison in the breathing protocol and when breathing comfortably.**



Note: Generated on <https://app.diagrams.net/> website by the authors.

Ranking results are summarized in Table 4:

**Table 4. Ranks.**

|                                                            | N              | Mean Rank | Sum of Ranks |
|------------------------------------------------------------|----------------|-----------|--------------|
| Slow-breathing protocol- Negative Ranks                    | 2 <sup>a</sup> | 4.75      | 9.50         |
| (avg HRR) - Comfortable breathing (avg HRR) Positive Ranks | 6 <sup>b</sup> | 4.42      | 26.50        |
| Ties                                                       | 2 <sup>c</sup> |           |              |
| Total                                                      | 10             |           |              |

a. Slow-breathing protocol (avg HRR) < Comfortable breathing (avg HRR)

b. Slow-breathing protocol (avg HRR) > Comfortable breathing (avg HRR)

c. Slow-breathing protocol (avg HRR) = Comfortable breathing (avg HRR)

The average heart rate recovery (HRR) means were exactly the same (130 bpm) for both the proposed breathing protocol and while breathing comfortably. Moreover, the standard deviation of the average (HRR) in the proposed breathing protocol and while comfortably breathing was 10.99 and 13.67 respectively. In addition to that, the lowest (HRR)

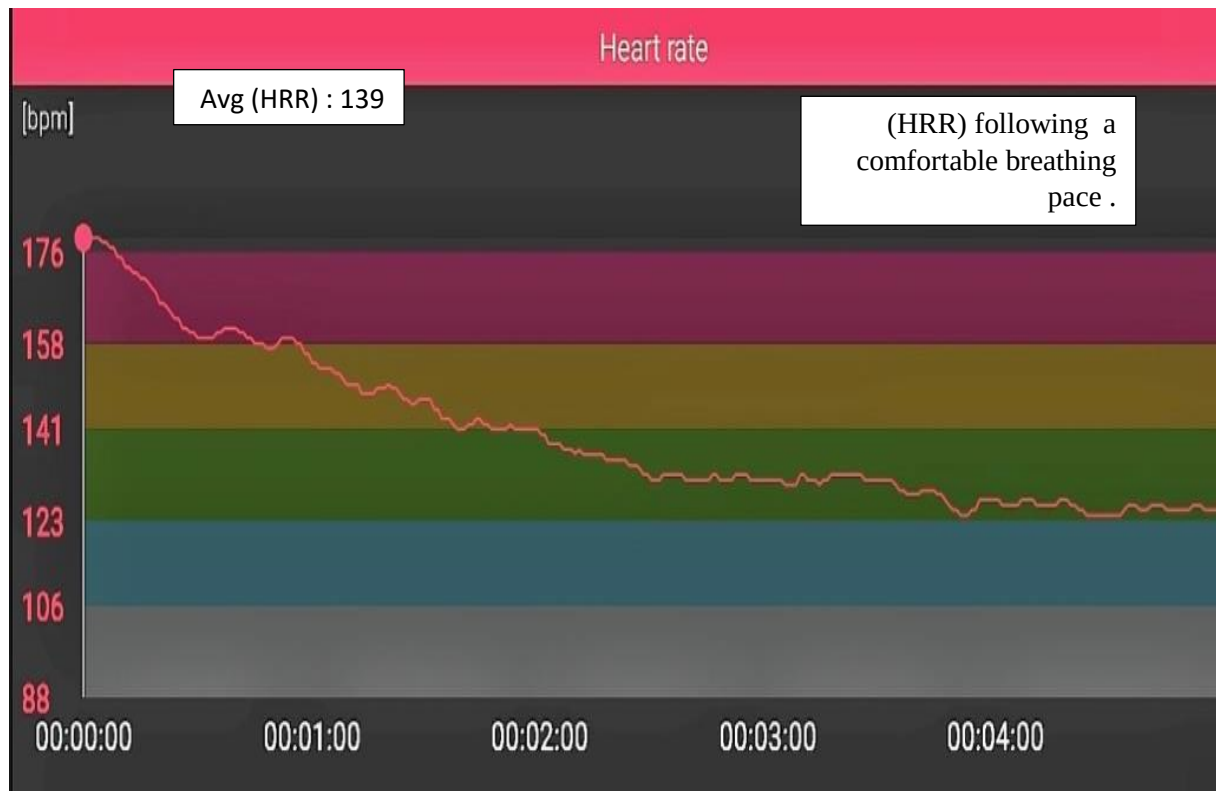
average was while breathing comfortably (114 bpm). It is noteworthy that the participant with the lowest average (HRR) had the lowest resting heart rate (RHR). In contrast, the one with the highest (RHR) had the highest average (HRR). More details are in table 5:

**Table 5: Descriptive statistics of the average (HRR).**

|                                 | N  | Mean   | Std. Deviation | Min | Max | Percentiles |               |        |
|---------------------------------|----|--------|----------------|-----|-----|-------------|---------------|--------|
|                                 |    |        |                |     |     | 25th        | 50th (Median) | 75th   |
| Comfortable breathing (avg HRR) | 10 | 130.10 | 13.666         | 114 | 156 | 117.00      | 128.50        | 140.50 |
| Breathing protocol (avg HRR)    | 10 | 130.10 | 10.989         | 117 | 148 | 118.00      | 131.00        | 140.50 |

Additionally, the curve of the (HR) displayed a remarkable fluctuations during the proposed breathing protocol, i.e., the (HR) curve increased when the participant was inhaling, while it decreased during the exhalation phase. This was more noticeable within the last 3 minutes of the recovery phase. The following two figures (3,4) are examples of heart rate recovery curve comparison between the proposed breathing protocol and when breathing comfortably for same the participant.

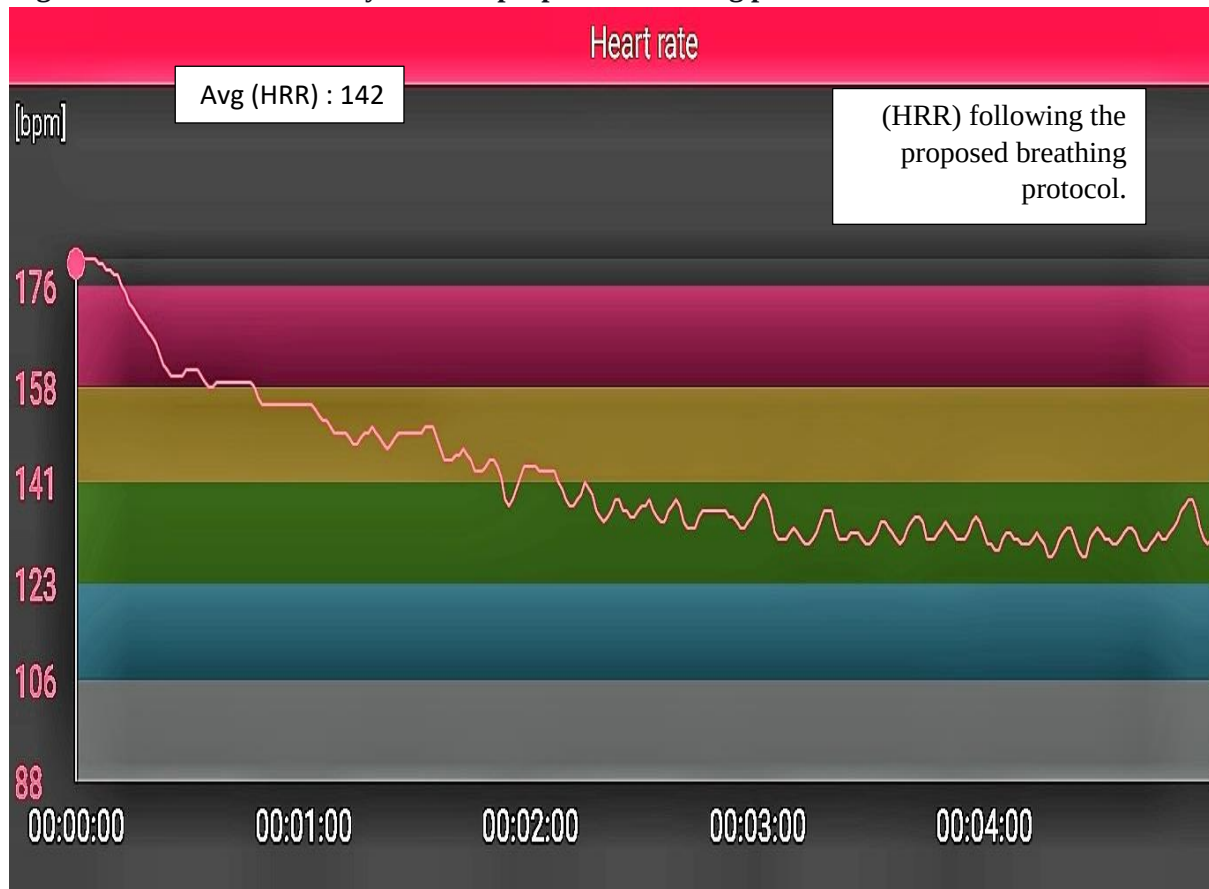
**Figure.3. Heart rate recovery curve when breathing comfortably.**



Note: Generated by the by the Polar Beat App.

In the following figure (figure 4), the heart rate (HR) curve fluctuations are more remarkable after the 2nd minute. There was a synchronization between the breathing cycles and the (HR) curve. It follows the proposed slow-breathing protocol cycles.

**Figure.4. Heart rate recovery with the proposed breathing protocol..**



*Note:* Generated by the by the Polar Beat App.

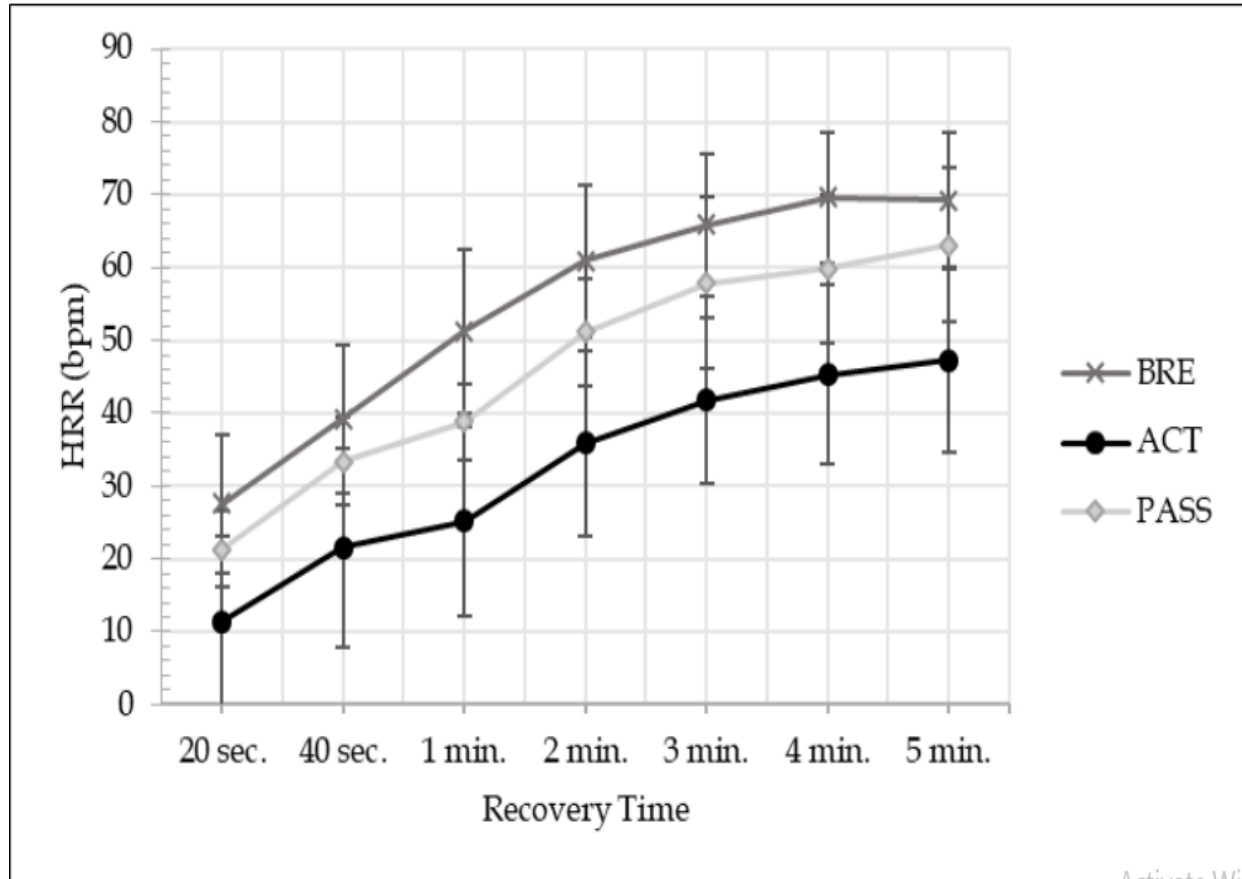
#### 4. Discussion:

In disagreement with our hypothesis, the post-exercise breathing pace at (7.5 breaths per minute) did not increase the average (HRR) after a 60-second all-out exercise (anaerobic lactic exercise) compared with the control test (while breathing comfortably). However, Zumbro et al. (2019) found that a slow breathing pace of six breaths per minute results in an increased (HRR), but this was after a 15-minute aerobic exercise (Figure 5). This contrast in results can be explained by the different accomplished exercise types (Kaikkonen et al., 2008) because the latter affects (HRR). (Anđić et al., 2016)

The other reason behind the contrast in results is that in Zumbro et al. study, the (HRR) measuring time was taken at (1min, 2min, 3min, 4min, and 5min.) this will be synchronized with the end of the exhalation phase of the breathing cycle due to the conducted breathing pace (6 breaths per minute), while in those moments the (HR) slightly decrease. The opposite happened in the inhalation phase. (Yasuma & Hayano, 2004). According to Candia-Rivera et al. (2022), the effect of breathing on heart rate, i.e., the increase of heart rate during the inspiration phase and its decrease during the expiration phase, is termed respiratory sinus arrhythmia (RSA).

These fluctuations in (HR) during the recovery phase are demonstrated in Figure (3,4). This must be taken into consideration to control its influence on (HRR). This is one of the reasons why we established (HRR) measurements as the average (HR) within all the recovery phase, and not only at some specific moments.

**Figure.5. Heart rate recovery curve after different recovery protocols.**



Data is expressed as mean  $\pm$  SD. n = 9; Values expressed as beats per minute (bpm); HRR = heart rate recovery; PASS = passive recovery; ACT = active recovery; BRE = breathing at 6 breaths per minute during recovery.

*Note:* From "The Influence of a Slow-Breathing Protocol on Heart Rate and Blood Pressure from Exercise in Moderately Trained Females" Zumbro, E. L., Ryan, G. A., Rossi, S. J., & Dobson, J. L. *International Journal of Exercise Science*, 12 (2), p719 ([Microsoft Word - 2459 Zumbro Formatted Final.docx \(wku.edu\)](#)). Copyright 2019 by *International Journal of Exercise Science*.

In another research paper, the participants performed three 30-s bouts of high-intensity cycling bouts with 4-minute recovery intervals. They hyperventilated for 20 minutes before the first bout and during each recovery interval. The results demonstrated that (HRR) during the exercise and post-exercise recovery intervals was lowered by the hypocapnia caused by voluntary hyperventilation. However, this effect diminished with repeated exercise bouts. (Dobashi et al., 2017). These findings suggest that prior and post-exercise hyperventilation can accelerate the (HRR).

In the present study, we found that the participant with the lowest average (HRR) had the lowest (RHR) in contrast, the one with the highest (RHR) had the highest average (HRR). This further strengthens the link between (HRR) and (RHR) and, consequently, the link between (HRR) and cardiorespiratory fitness. Because the latter was found to be associated with (RHR). (Kang et al., 2017). Therefore, an unhealthy lifestyle has a significant negative impact on both the cardiorespiratory fitness and HRR (Fan et al., 2020). These findings agree with results previously published by Watson et al. 2017 and Bunn et al. 2018.

### Conclusions and suggestions:

Our findings indicate that a breathing pace of 7.5 breaths per minute did not show a significant enhancement in the average (HRR) after an All-out 60-second pedaling exercise. Nevertheless, this proposed breathing protocol seems to affect the (HR) curve within the last 3 minutes of the recovery phase protocol, i.e., the (HR) curve increases when the participant is inhaling, while it decreases during the exhalation phase, creating synchronized fluctuations with the breathing cycle. Yet, further research is still needed for more understanding of the physiological aspect to help establish better breathing techniques for recovery. The percentage of oxyhemoglobin (HbO<sub>2</sub>) measurement in the total blood hemoglobin should be used to determine the effect of the slow breathing techniques on SatO<sub>2</sub>, because this may lower the amount of oxygen entering the body. Consequently, the oxygen debt period would extend.

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