EXTREME PHYSIOLOGY IN ARTISTIC SWIMMING

MINISTERIO DE EDUCACIÓN, FORMACIÓN PROFESIONAL Y DEPORTES

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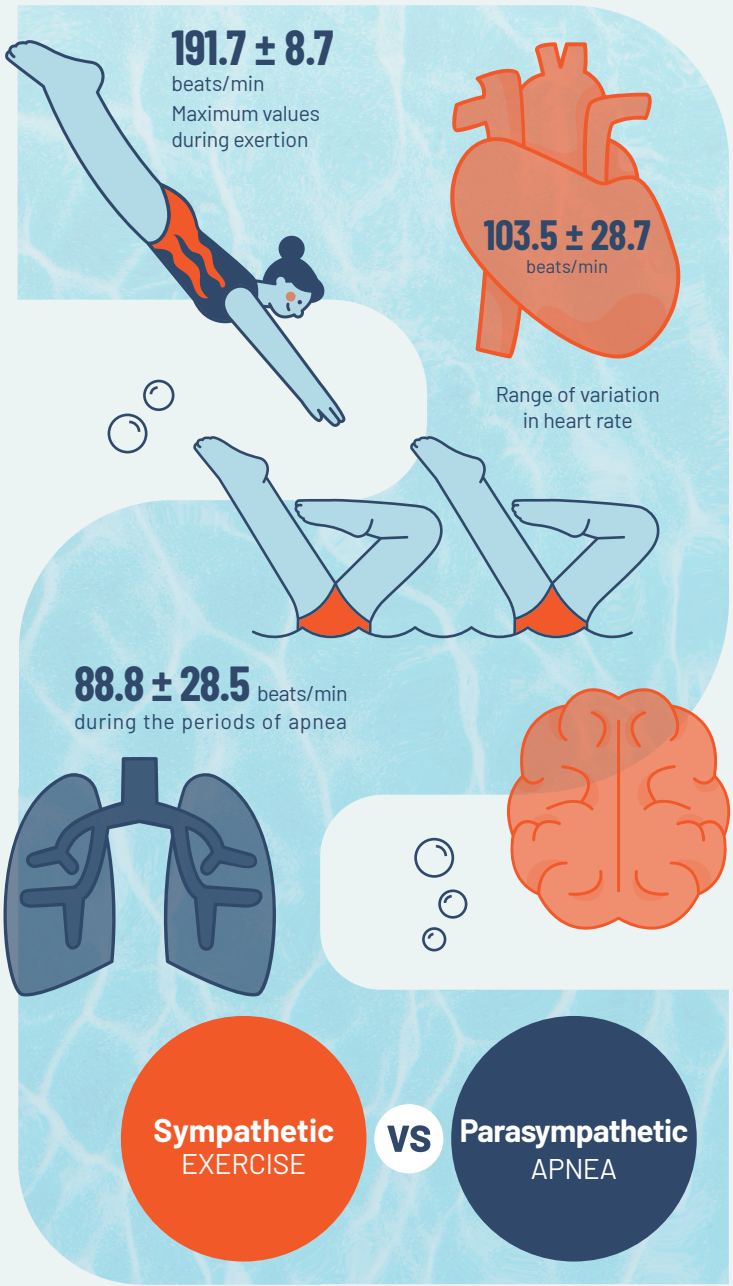
1. Unique cardiovascular demands

High cardiovascular demands: the routines produce elevated maximum heart rates, interspersed with episodes of **bradycardia** caused by apnea.

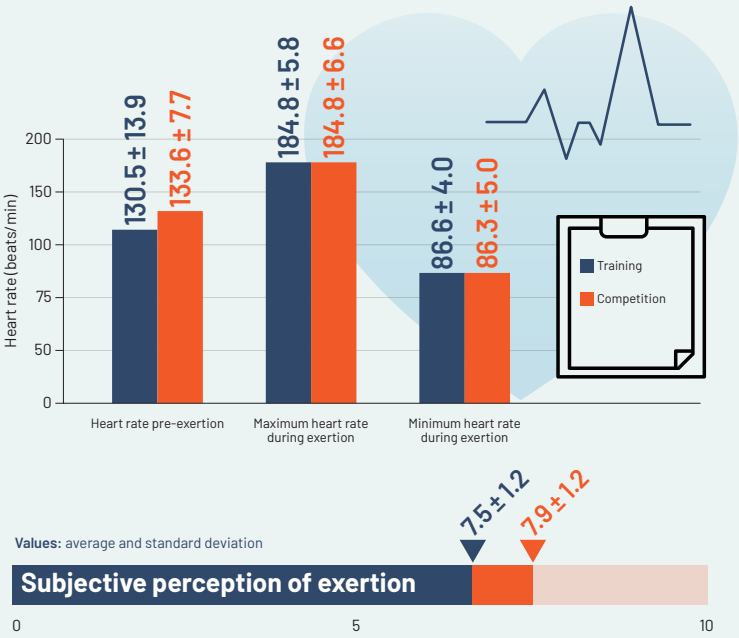


KEY IDEA 1

Pronounced and immediate lowering of heart rate (HR) due to the apnea, and a rise due to breathing + exertion.

2. Similarity between training and competition

In duet routines for artistic swimming, the values for **HR** and rate of **perceived exertion (RPE)** are very similar for both training and competition.



Equivalence between training and competition: the routines make similar physiological demands in training and competition, with regard to both **objective indicators** (heart rate) and **subjective indicators** (rate of perceived exertion, RPE).

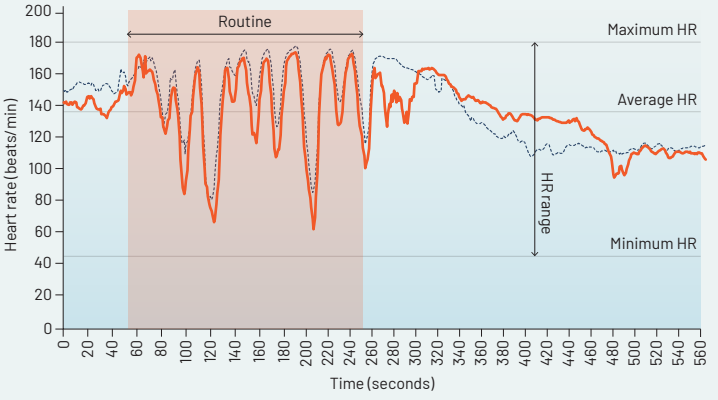


Figure 3. Heart rate of one of the swimmers before, during (shadowed area) and after a duet free routine performed during training (blue line) and competition (red line). Real data obtained during training and competition.

KEY IDEA 2

A similar phenomenon is observed in both training and competition, in the same routine performed by the same swimmer.

Rodríguez-Zamora, L., et al. (2012, 2014a, 2014b): https://doi.org/10.1371/journal.pone.0049098 - https://doi.org/10.1519/JSC.0b013e3182a20ee7 - https://doi.org/10.1055/s-0033-1353177

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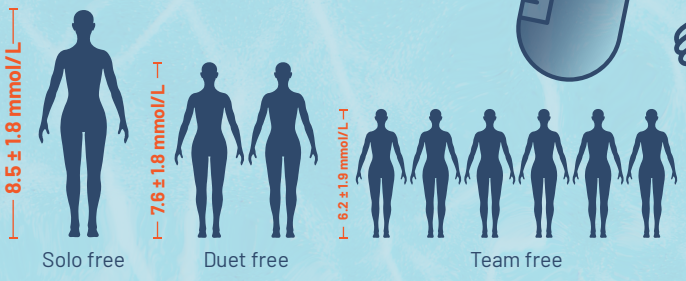
3. Blood lactate

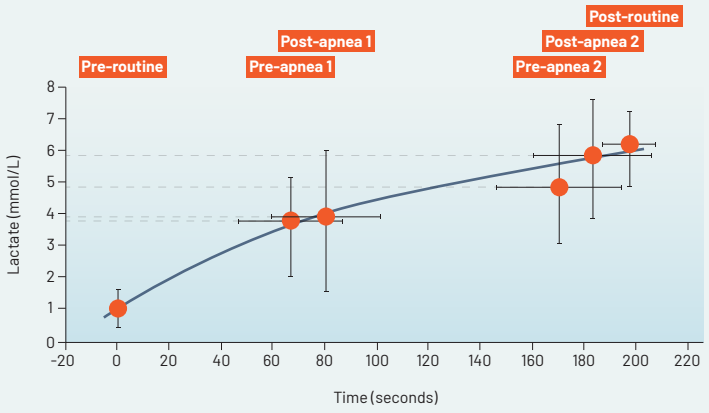
Moderate accumulation in all of the routines.

Peak values La_{peak} → **7.3 ± 2.7 mmol/L**

Significant differences between routines:



*Values from a sample of 96 routines performed in an official competition.



The lactate **gradually increases** by a significant amount ($p < 0.01$) as the **duet free** routine progresses ($n = 16$), thus indicating a **cumulative impact of physical exertion**.

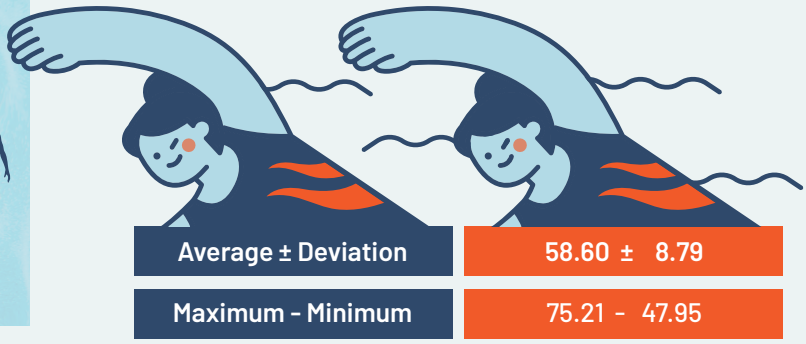
KEY IDEA 3

- The accumulation appears to be mostly caused by the high energy demands of the exertion, and not by the apnea.
- The peak values for blood lactate (Lapeak) are generally obtained between minutes 5 and 7 of the post-routine recovery period.

4. Oxygen consumption

- Rapid increase in **VO_2 (cardiorespiratory capacity)** during exertion.
- No differences in **VO_2** were observed before/after **prolonged apneas**.

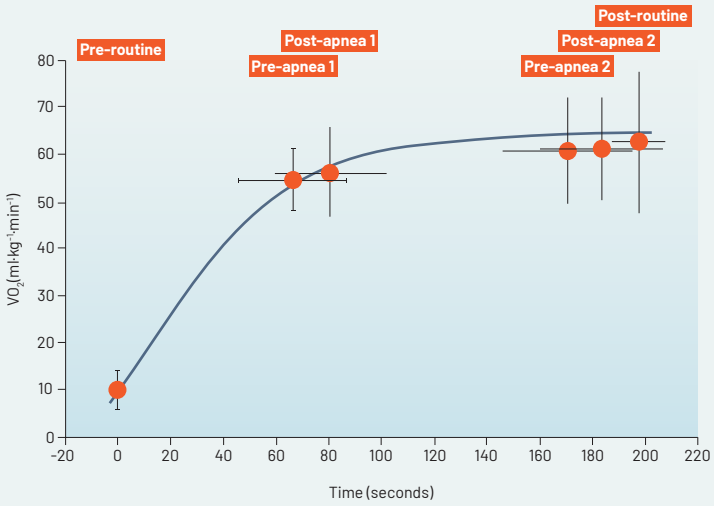
Average peak oxygen consumption values for **16 elite artistic swimmers**, measured on five separate occasions during a **duet free** routine.



Average ± Deviation	58.60 ± 8.79
Maximum - Minimum	75.21 - 47.95

*Values in mL/min/kg.

Measurement of **oxygen consumption** obtained by segmenting **duet free** routines based on the two figures with the highest apnea:



KEY IDEA 4

No significant differences in VO_2 or blood lactate were observed before or after prolonged apnea.

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5. Rate of perceived exertion

Increased rate of perceived exertion associated with:

- Increased **duration/frequency** of bradycardia events.
- Lower **average** and **minimum** heart rates.
- **Greater** range of variation in heart rate.
- There is a correlation between **lactate** and **rate of perceived exertion**.

The La_{peak} correlates positively with the values for rate of perceived exertion (RPE) reported by the swimmers ($R = 0.50$, $P = 0.003$).

Correlations

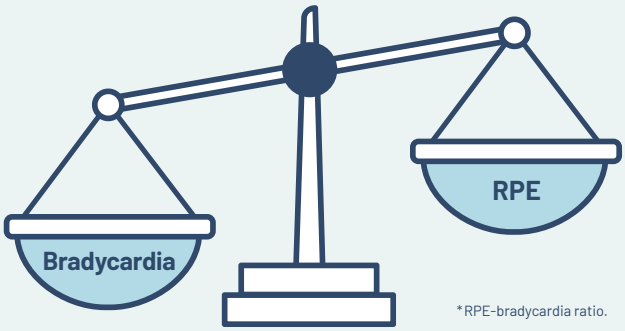
Inverse with minimum HR (R=-0.545)

Average HR (R=-0.452)

Positive with HR range (R=0.520)

La_{peak} (R=0.50)

*Solo and duet routines, both technical and free, in elite swimmers (n = 30).



*RPE-bradycardia ratio.

RPE as a practical tool

Rate of perceived exertion (RPE) is a viable, cost-effective and non-invasive alternative method for **monitoring internal load**.

KEY IDEA 5

The lower the minimum and average heart rates during the routines, the higher the swimmers' rate of perceived exertion.

6. Conclusions: apnea and adaptation

Artistic swimming produces a unique physiological response due to the alternation between **intense exertion and prolonged** apnea:

1 Time under the water

- For the majority of the routine, the swimmers are under the water.
- 61.6 ± 6.4% of total time in apnea.

Cardiovascular response 2

- The facial immersion and apnea rapidly activate the parasympathetic system and cause bradycardia.
- The intense exertion stimulates the sympathetic system and increases the heart rate.
- Both systems compete to control the heart rate during the routines.

Unique heart rate pattern 3

- Alternating periods of tachycardia (due to exertion) and bradycardia (due to immersion).
- Rapid increases and decreases in heart rate.
- Artistic swimming is unique because, although the intensity of exertion is increased, the swimmer's heart rates are lowered as a result of the apneas.

4 Adaptation in elite swimmers

- Increased capacity to maintain apnea.
- More pronounced bradycardia response during immersion.
- Suggestive of improved adaptation on the part of the parasympathetic system

KEY IDEA 6

This alternation between extreme maximum and minimum heart rate values is due to the interaction between the sympathetic activation catalysed by the intense exertion and the parasympathetic activation catalysed by the intermittent apneas during the routines.

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