



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## HYPOXIC INTER-EFFORT RECOVERY DURING SPRINT INTERVAL TRAINING EXERCISE ENHANCES OXYGEN UPTAKE AT THE ONSET OF EFFORTS WHILE MAINTAINING EXERCISE TOLERANCE

### Authors:

Norberto M.S.<sup>1</sup>, Putti G.M.<sup>2</sup>, Figueira T.R.<sup>2</sup>, Dellavechia de Carvalho C.<sup>1</sup>, Rasteiro, F.M.<sup>3</sup>, Morostegan A.B.<sup>3</sup>, Manchado-Gobatto, F.B.<sup>3</sup>, Gobatto, C.A.<sup>3</sup>, Papoti, M.<sup>2</sup>.

<sup>1</sup> University of São Paulo-USP

<sup>2</sup> University of Campinas-UNICAMP



gecifex

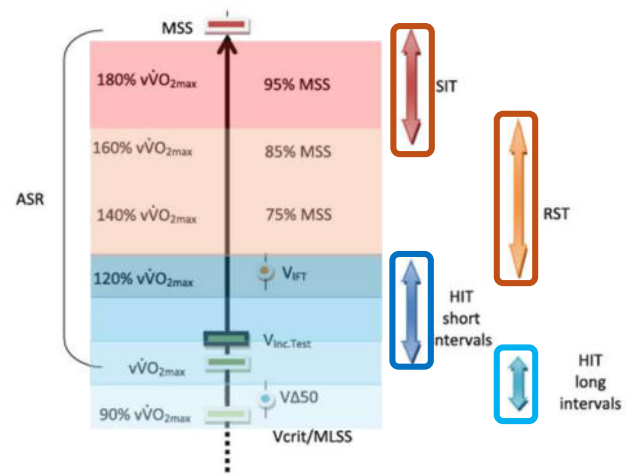


LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE

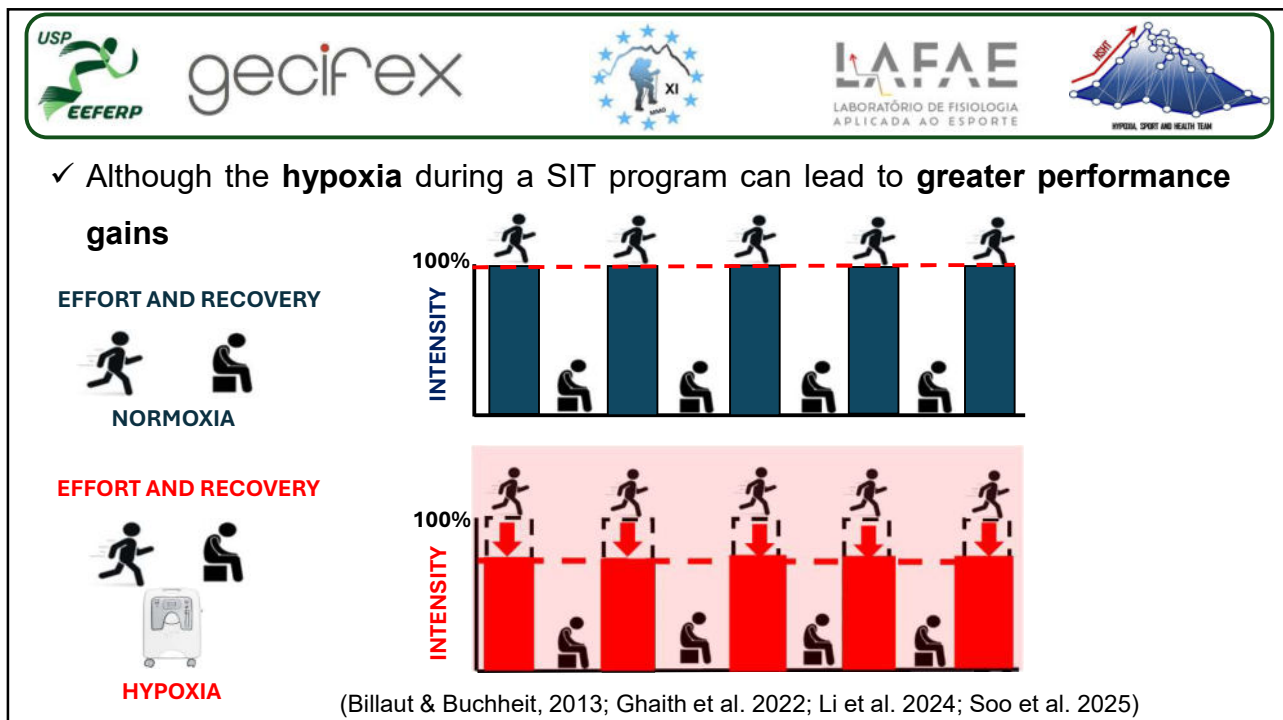
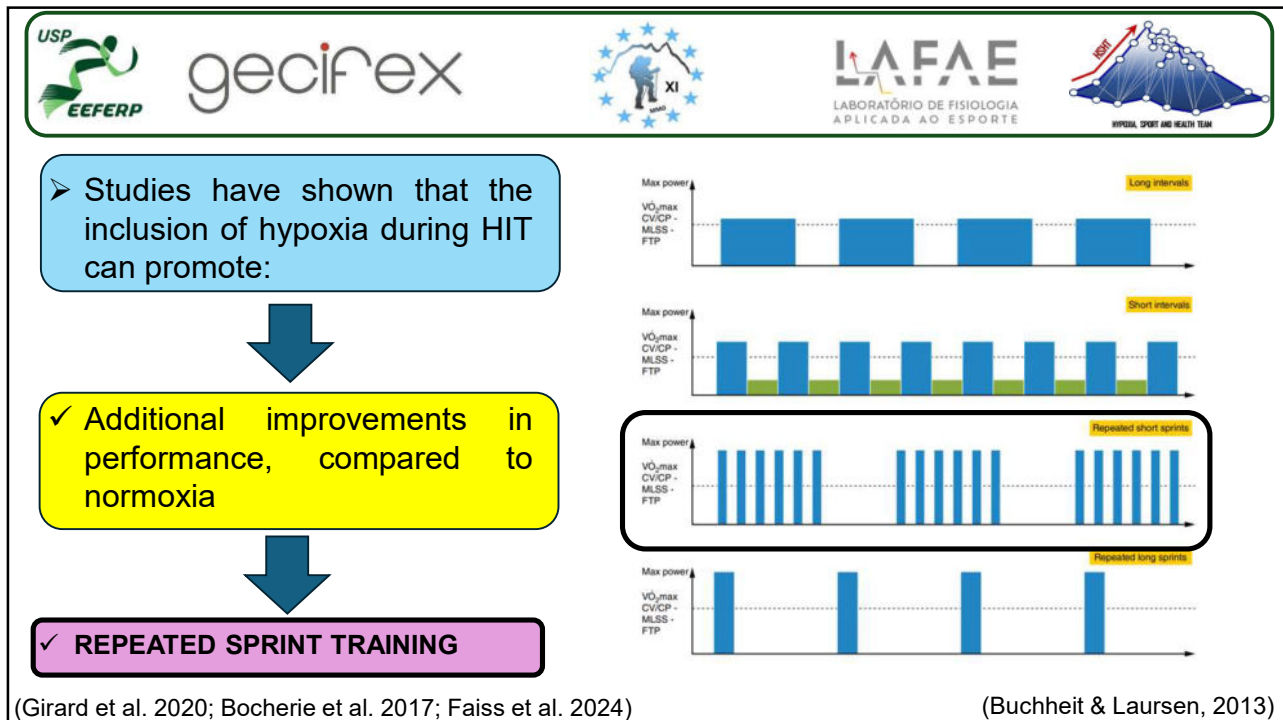


## High-intensity interval training (HIT)

- Repeated efforts of high-intensity exercise
- Alternating with active or passive recovery periods
- Enhance athletic performance and improve health-related parameters



(Buchheit & Laursen, 2013)





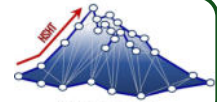
gecifex

LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE

When the goal is to **maximize athletic performance**, the **challenge** lies in increasing the **physiological stress** induced by the training session without reducing the external load !



gecifex

LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE

## HOW ACHIEVE?

➤ **BENEFITS INDUCED BY HYPOXIA**

➤ **MAINTENANCE OF THE QUALITY AND INTENSITY OF THE TRAINING SESSIONS**

➤ **APPLICATION OF HYPOXIA IN REAL-WORLD SETTINGS?**



➤ We recently **proposed** and **found** evidence suggesting that...

Open access Viewpoint

**BMJ Open Sport & Exercise Medicine**

**Inter-effort recovery hypoxia: a new paradigm in sport science?**

Marcelo Papoti<sup>a,\*</sup>, Fúlvia Barros Manchado-Gobatto<sup>a,2</sup>, Claudio Alexandre Gobatto<sup>a,2</sup>

PHYSIOLOGY

**ACUTE PHYSIOLOGICAL RESPONSES TO "RECOVERY INTERMITTENT HYPOXIA" IN HIIT**

RESPOSTAS FISIOLÓGICAS AGUDAS À "HIPOXIA INTERMITENTE DE RECUPERAÇÃO" NO HIIT

RESPUESTAS AGUDAS A LA "HIPOXIA INTERMITENTE DE RECUPERACIÓN" EN EL HIIT

**Recovery in normobaric hypoxia as an additional stimulus for high-intensity intermittent training**

Récupération en hypoxie normobare comme stimulus supplémentaire pour un entraînement intermittent de haute intensité

C. Dellavechia de Carvalho<sup>a,\*</sup>, G. Marcolino Putti<sup>b</sup>, Y. Figueiredo Foresti<sup>b</sup>, F. Alves Ribeiro<sup>b</sup>, J. Causin Andreossi<sup>b</sup>, G. Ferraz de Campos<sup>b</sup>, M. Papoti<sup>a,b</sup>

ORIGINAL ARTICLE

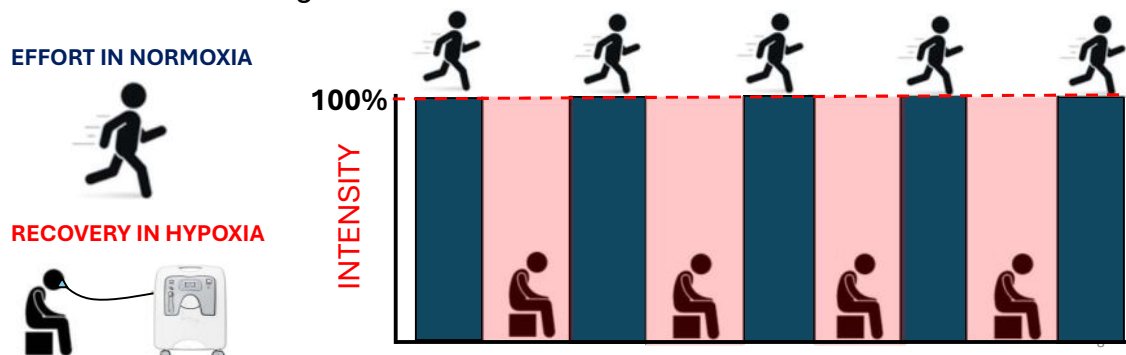
**Standardization of evaluation and exercise prescription for deep water running with normobaric hypoxia exposure**

Standardisation de l'évaluation et de la prescription d'exercices pour la course en piscine profonde avec exposition à une hypoxie normobare

C.D. Carvalho<sup>a,\*</sup>, G.D. Ferronato<sup>b</sup>, V.M. Coelho-Ruzzi<sup>b</sup>, M. Papoti<sup>a,b</sup>



➤ Adding during **Inter-Effort Hypoxia** exclusively during recovery periods (**IEH**) of interval training sessions



✓ Could be a **more effective approach** than training performed under hypoxia.



gecifex

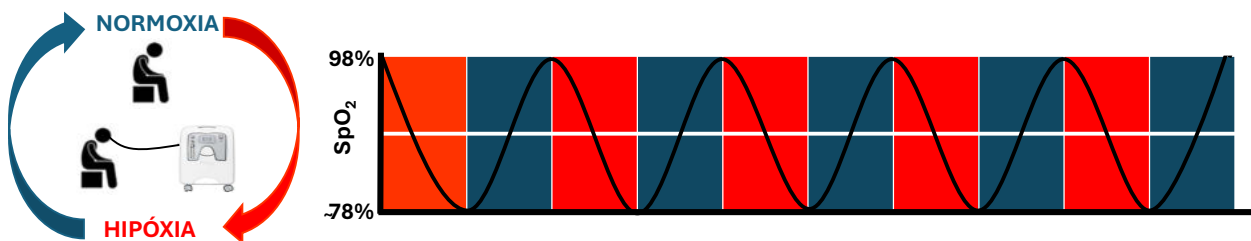


LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## RATIONALE

- ✓ Alternating cycles of **oxygenation and deoxygenation** facilitate the maintenance of exercise intensity by **enhancing oxygen availability** in the active musculature.



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



### Recovery in normobaric hypoxia as an additional stimulus for high-intensity intermittent training

*Récupération en hypoxie normobare comme stimulus supplémentaire pour un entraînement intermittent de haute intensité*

C. Dellavechia de Carvalho<sup>a,\*</sup>, G. Marcolino Putti<sup>b</sup>,  
Y. Figueiredo Foresti<sup>b</sup>, F. Alves Ribeiro<sup>b</sup>, J. Causin Andreossi<sup>b</sup>,  
G. Ferraz de Campos<sup>b</sup>, M. Papoti<sup>a,b</sup>

### PHYSIOLOGY

### ACUTE PHYSIOLOGICAL RESPONSES TO "RECOVERY INTERMITTENT HYPOXIA" IN HIIT

*RESPOSTAS FISIOLÓGICAS AGUDAS À "HIPÓXIA INTERMITENTE DE RECUPERAÇÃO" NO HIIT*

*RESPUESTAS AGUDAS A LA "HIPOXIA INTERMITENTE DE RECUPERACIÓN" EN EL HIIT*

- ✓ **Exercise capacity** was preserved during **10 x 1min with 2min recovery @ 100% and 120% of the maximal aerobic velocity** with the addition of hypoxia applied during the **inter-effort recovery periods**



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



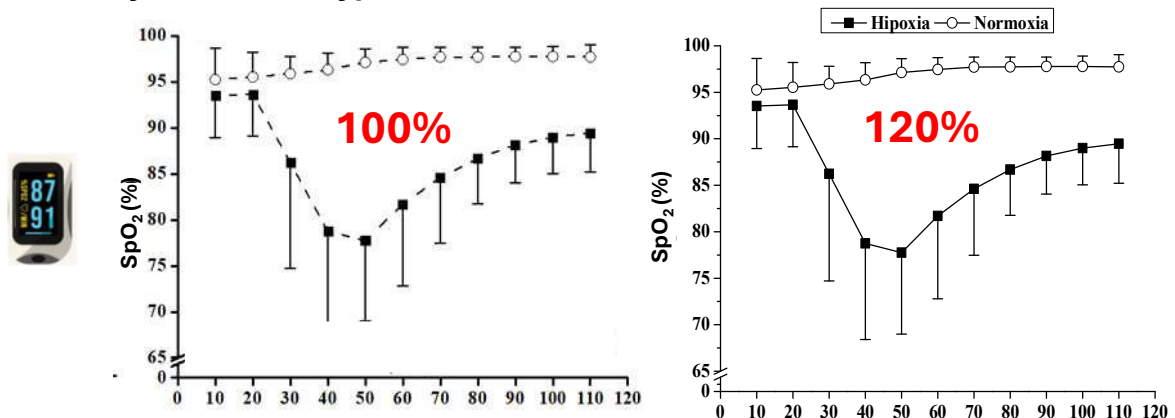
gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



- ✓ Although **peripheral oxygen saturation** was significantly **reduced** during **recovery intervals in hypoxia**







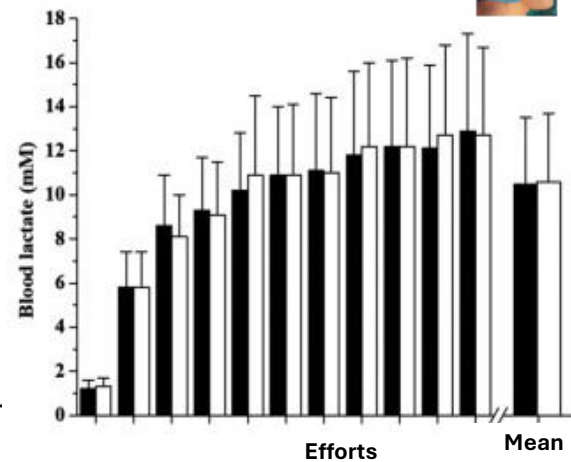
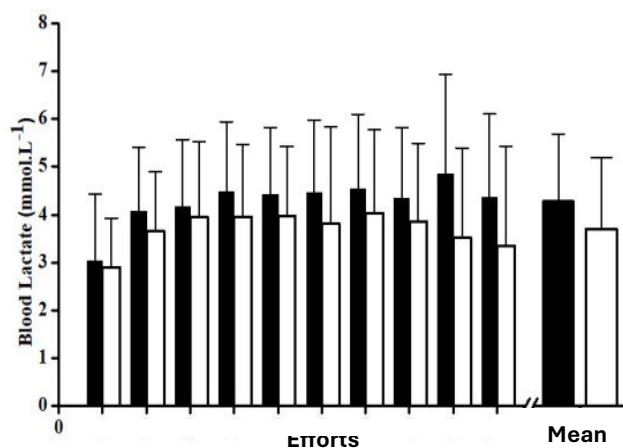
gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



✓ The blood lactate concentrations did **not** differ between conditions



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



✓ We recently presented at **ECSS** the effects of **IEH in swimmers** during **all-out** sprint interval training

**INTER-EFFORT HYPOXIA RECOVERY EXACERBATES INTERNAL LOAD DURING ACUTE SPRINT INTERVAL TRAINING SESSIONS WITHOUT COMPROMISING PERFORMANCE IN SWIMMER**

**Authors:**

PAPOTI, M<sup>1</sup>, ESEQUIEL, G.H.S<sup>1</sup>, RIBEIRO F.A<sup>1</sup>, MIRANDA, D.R.M<sup>1</sup>, CARVALHO, C.D<sup>1</sup>, FORESTI, Y.F<sup>1</sup>, GOBATO, C.,A<sup>2</sup>, MACHADO-GOBATTO, F.B<sup>2</sup>, FIGUEIRA, T.R<sup>1</sup>.





gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## METHODS



(n=24)

	Efforts number	Efforts Distance	Recovery (min)	Intensity
SIT1	20	25m	1.5	All-out
SIT2	10	50m	3.0	All-out

✓ EFFORTS → NORMOXIA

✓ RECOVERY → HYPOXIA



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## ➤ EXPERIMENTAL SETUP FOR HYPOXIA GENERATION



✓ AIR STORAGE "BAGS"



✓ NITROGEN GAS GENERATOR



✓ VALVE SYSTEM



✓ UNIDIRECTIONAL MASK

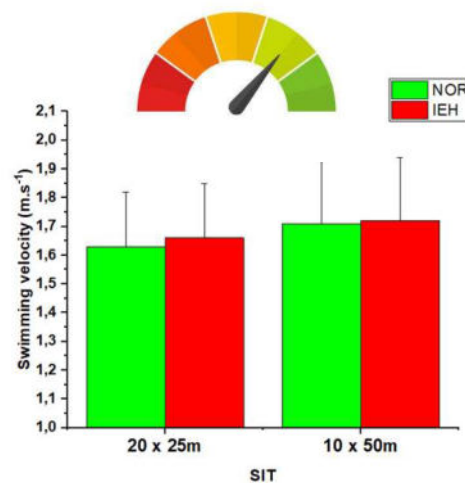
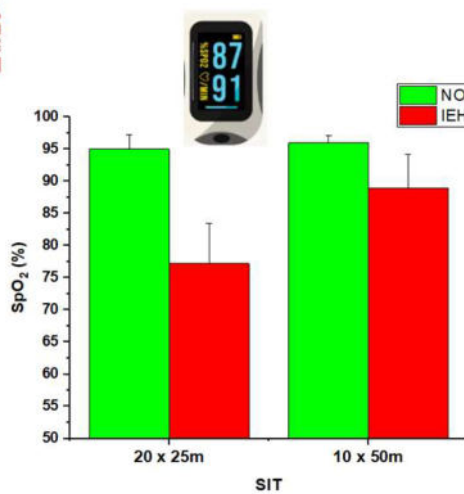




gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE





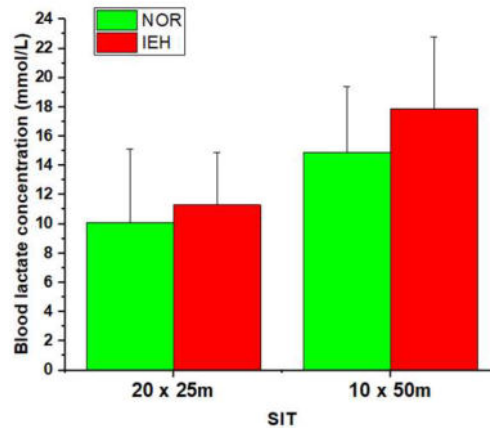
gecifex



LAFAE  
LABORATÓRIO DE FISIOLOGIA  
APLICADA AO ESPORTE



## ✓ RESULTS



✓ [La] were **not** significantly different between conditions



gecifex



LAFAE  
LABORATÓRIO DE FISIOLOGIA  
APLICADA AO ESPORTE



So far, we have identified the effects of hypoxia during inter-effort. Now, our goal is to understand **why exercise intensity is preserved** despite the reduced oxygen availability ?



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## OBJECTIVE

- This study aimed to compare the **acute effects** of oxygen uptake, muscle oxygenation and exercise tolerance during a session of SIT in **normoxia**, **continuous hypoxia** and **inter-effort hypoxia** recovery.



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



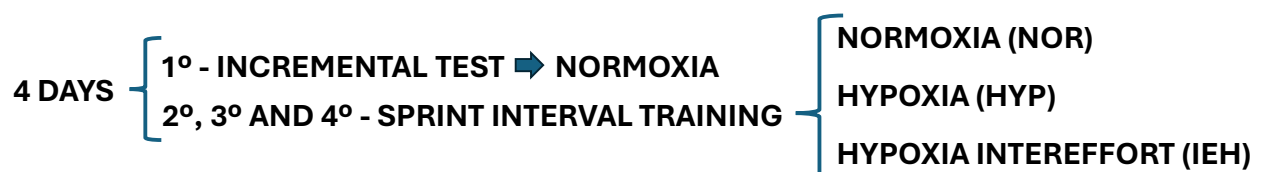
## METHODS

- The single-blind randomized crossover experimental design involved:

**12 recreational runners**

Age	Body Mass	Height	VO <sub>2</sub> peak
24 ± 5	74 ± 14	174.5 ± 9	49.8 ± 5

## EXPERIMENTAL DESIGN





gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE

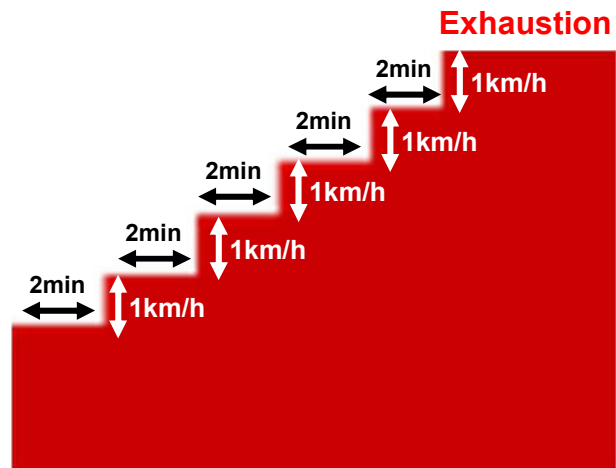


## INCREMENTAL TEST

**Warm-up:** 5-min at 7 km/h,

**Efforts:** 2min

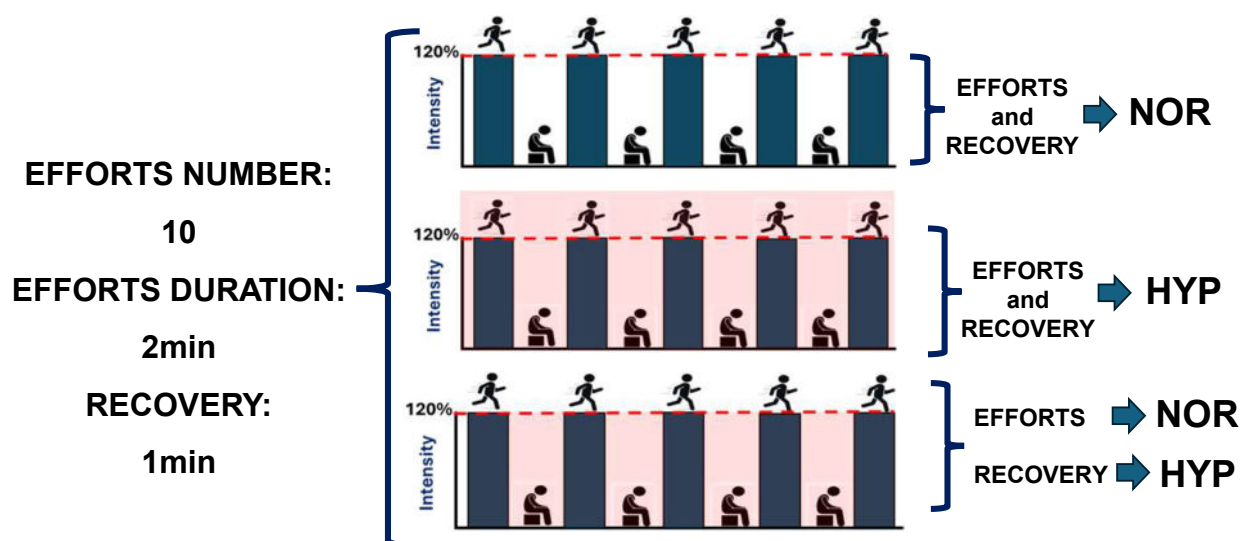
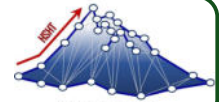
**Increments:** 1km/h



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE





gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE

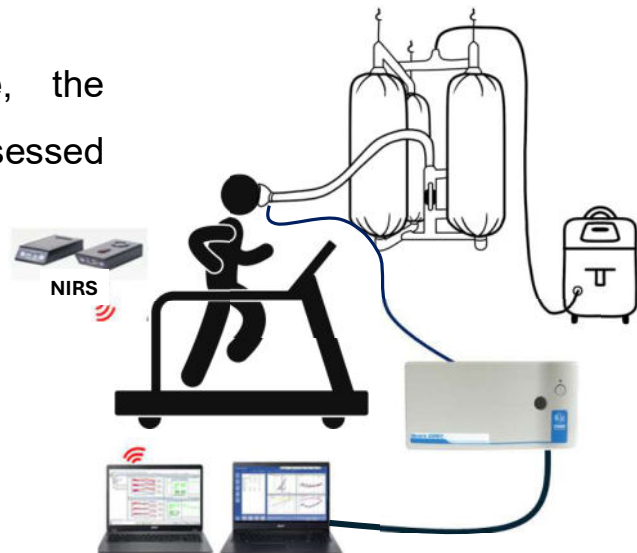


- During **rest** and **exercise**, the following parameters were assessed in the **SIT sessions**:



➤ **VO<sub>2</sub>**

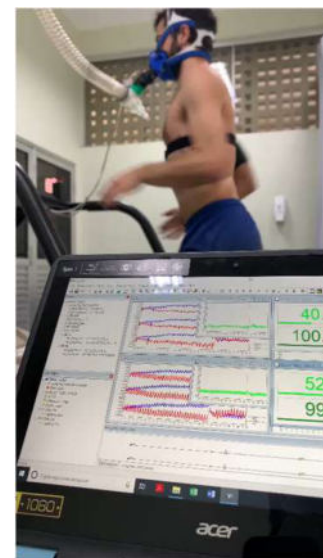
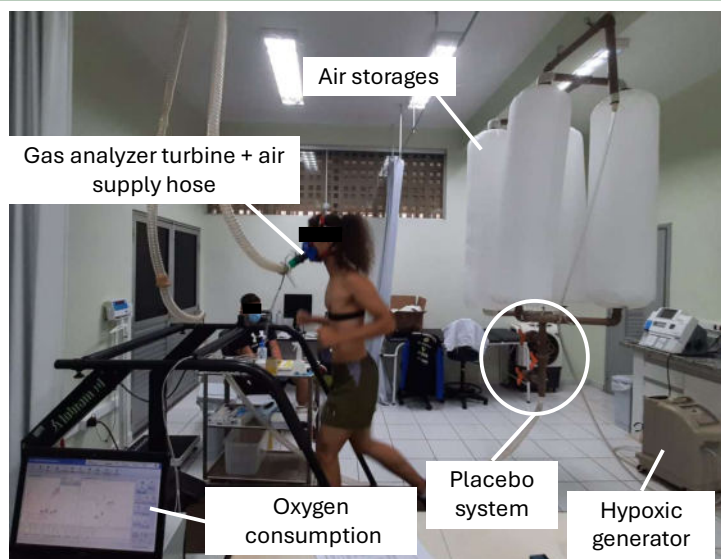
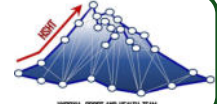
➤ **NIRs**



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE







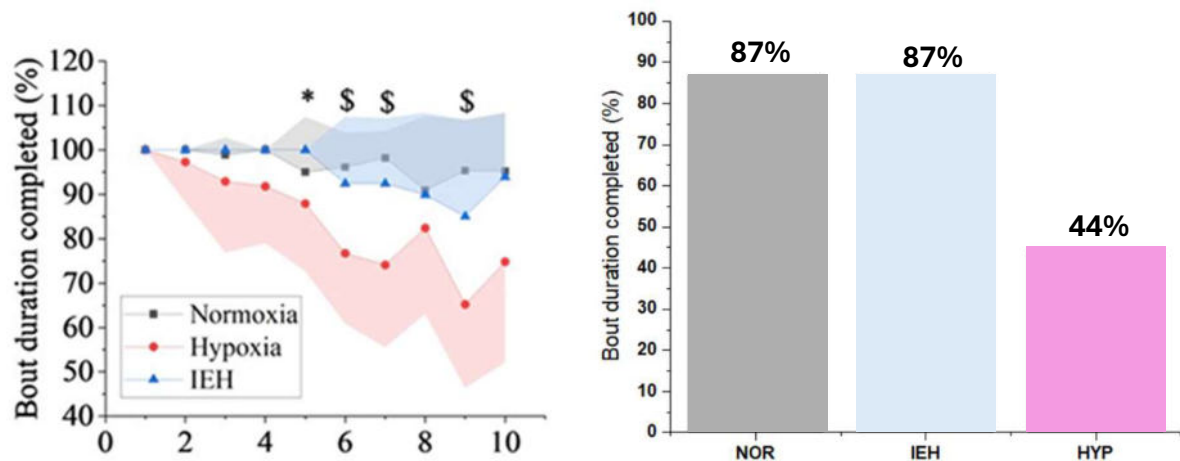
gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



The **success rate** in completing the SIT, was nearly identical between **NOR** and **IEH** conditions, but significantly lower in **HYP**



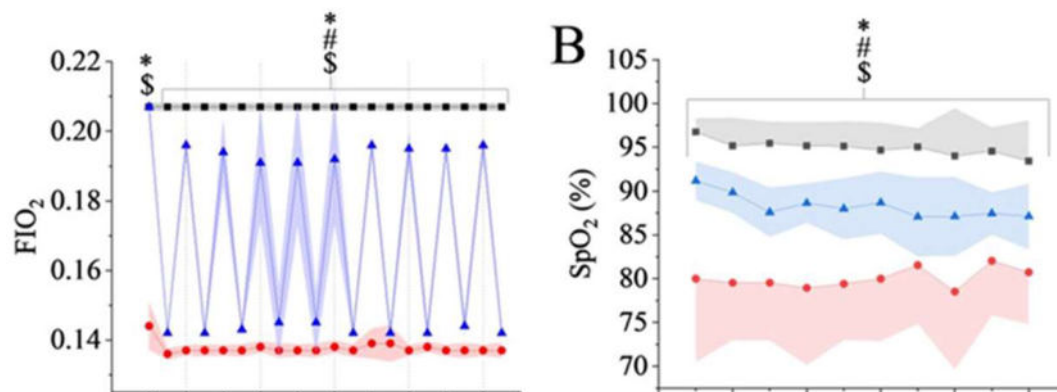
gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



- $\text{FiO}_2$  was maintained in **NOR**, reduced in **HYP** and oscillated in **IEH**.
- $\text{SpO}_2$  was stable in **NOR**, significantly reduced in **HYP** and intermediate values in **IEH**







gecifex

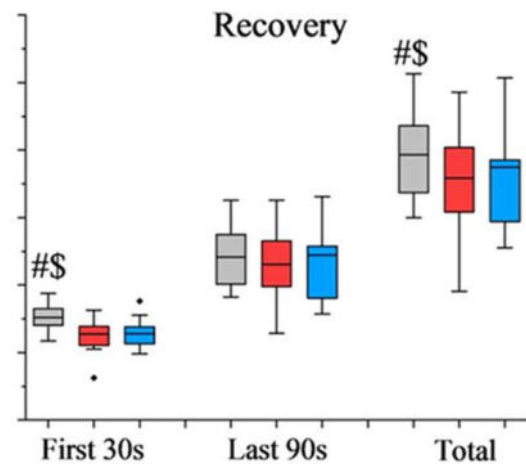


LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## RECOVERY:

- During recovery, **lower  $\text{VO}_2$  integrals** were observed in **hypoxia** and **IEH** conditions compared to normoxia.
- Both in the first 30 s and for the **total recovery period**.



gecifex

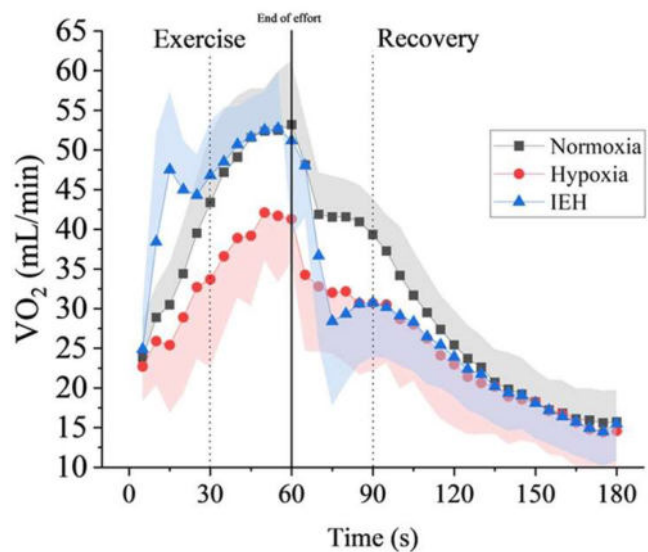


LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## EXERCISE:

- ✓ During **exercise**, the differences between conditions were **mostly** in the **first 30s**.
- ✓ The **IEH** led to **higher  $\text{VO}_2$  integral** during the first **30s of effort**, compared to other experimental conditions.





gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## RECOVERY

- During recovery, **HYP** induced a **significant increase in HHb** and a **reduction in TSI**, while **IEH** also resulted in a **lower TSI** compared to **NOR**.

RECOVERY	NOR	HYP	IEH
HHb (μM)	11.5 ± 5.5	<b>17.4 ± 6.7*</b>	14.5 ± 7.1
O <sub>2</sub> Hb (μM)	0.1 ± 8.3	-5.2 ± 6.5	-1.5 ± 6.2
tHb (μM)	12.4 ± 8	12.5 ± 7.1	13.8 ± 8.3
TSI (%)	59.6 ± 4.1	<b>55.2 ± 5.4*</b>	<b>56.8 ± 4.7*</b>

**HHb**: deoxyhemoglobin, **O<sub>2</sub>Hb**: oxyhemoglobin concentration, **tHb**: total hemoglobin (HHb+O<sub>2</sub>Hb), and **TSI**: tissue saturation index (O<sub>2</sub>Hb/tHb).



gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



## EXERCISE

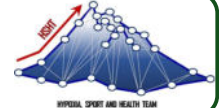
- Despite the reduced O<sub>2</sub> availability at rest, during **exercise the TSI under IEH** was **not** different from **NOR**.

EFFORT	NOR	HYP	IEH
HHb (μM)	10.2 ± 5.7	14.3 ± 7.5	10.6 ± 7.9
O <sub>2</sub> Hb (μM)	-14.1 ± 8.7	-18.1 ± 9.1	-14.1 ± 5.7
tHb (μM)	1.4 ± 6.4	1.2 ± 3.6	1.9 ± 6.9
TSI (%)	55.4 ± 4.7	<b>52.3 ± 6.1*</b>	54.1 ± 4.8

**HHb**: deoxyhemoglobin, **O<sub>2</sub>Hb**: oxyhemoglobin concentration, **tHb**: total hemoglobin (HHb+O<sub>2</sub>Hb), and **TSI**: tissue saturation index (O<sub>2</sub>Hb/tHb).



gecifex

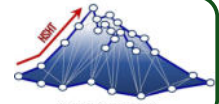
LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE

### ✓ CONCLUSION

- $\text{VO}_2$  is **increased** and **muscle oxygenation** is **maintained** at control levels **during efforts**.
- **Enhanced aerobic metabolism during efforts** was associated with **preserved exercise tolerance** in the **IEH condition**.
- This is an **advantage** over **HYP** during SIT exercise.



gecifex

LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE

**Next step...**

- ✓ Now our next goal is to investigate the potential **chronic effects** of **IEH**.

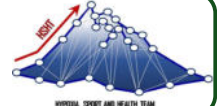




gecifex



LAFAE  
LABORATÓRIO DE FISIOLÓGIA  
APLICADA AO ESPORTE



**[mpapoti@usp.br](mailto:mpapoti@usp.br)**