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# Heat and water transfers in the bronchi: clinical insights from a theoretical modeling study

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## Background

Conditioning of air during respiration occurs in the upper airways, but also in the bronchi [McFadden, 1985].

Because it is related to the evaporation of the water contained in the mucus [Karamaoun, 2018], it could affect its dynamics, but also the body water and thermal balance.

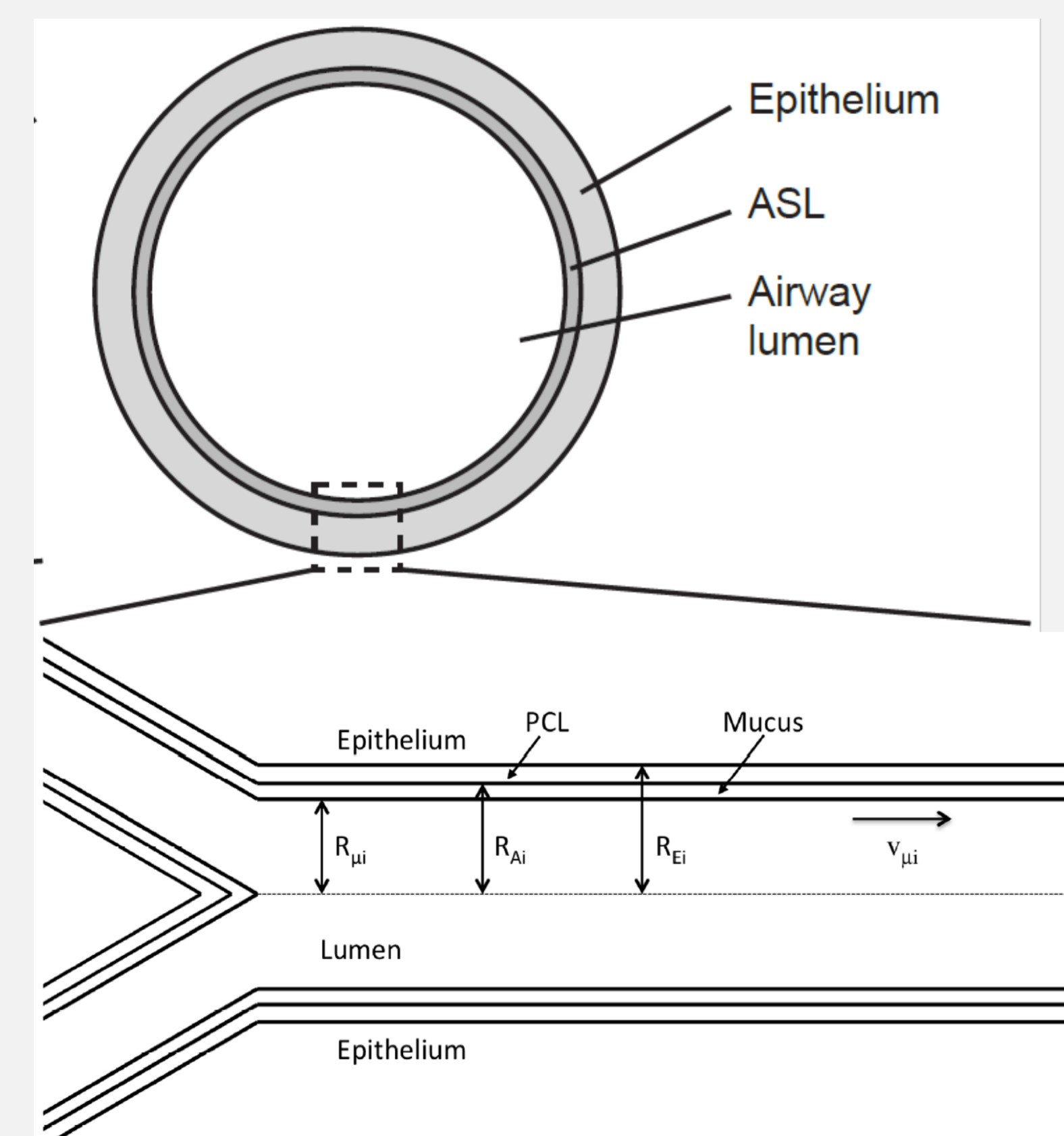
## Aim

To assess theoretically the influence of the bronchial evaporation on the mucus dynamics and on the body water and thermal balance.

Then, to issue recommendations for the management of airway pathologies.

## Methods

A theoretical model, previously developed [Karamaoun, 2018], is used with parameters simulating resting and exercise respiration in room conditions. Heat and water losses are computed for every bronchial generation.



$$V_{av} \frac{\alpha + 2}{\alpha} \left(1 - \left(\frac{r}{R_{\mu}}\right)^{\alpha}\right) \frac{\partial C}{\partial z} + \frac{\partial C}{\partial t} = D \frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial C}{\partial r}\right) + D \frac{\partial^2 C}{\partial z^2}$$

$$V_{av} \frac{\alpha + 2}{\alpha} \left(1 - \left(\frac{r}{R_{\mu}}\right)^{\alpha}\right) \frac{\partial T}{\partial z} + \frac{\partial T}{\partial t} = \kappa_a \frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial T}{\partial r}\right) + \kappa_a \frac{\partial^2 T}{\partial z^2}$$

The transport of heat in the ASL, the epithelium and the connective tissue layer is assumed to be purely radial and at quasi-steady state.

$$\frac{\kappa_l}{r} \frac{\partial}{\partial r} \left(r \frac{\partial T_l}{\partial r}\right) = 0$$

In the connective tissue surrounding the airway wall, the energy balance writes

$$\frac{dT_c}{dt} = \frac{P}{\rho_l c_{p,l}} - \frac{\kappa_l}{\delta_c} \frac{\partial T_l}{\partial r}$$

At the air-mucus interface, energy balance writes

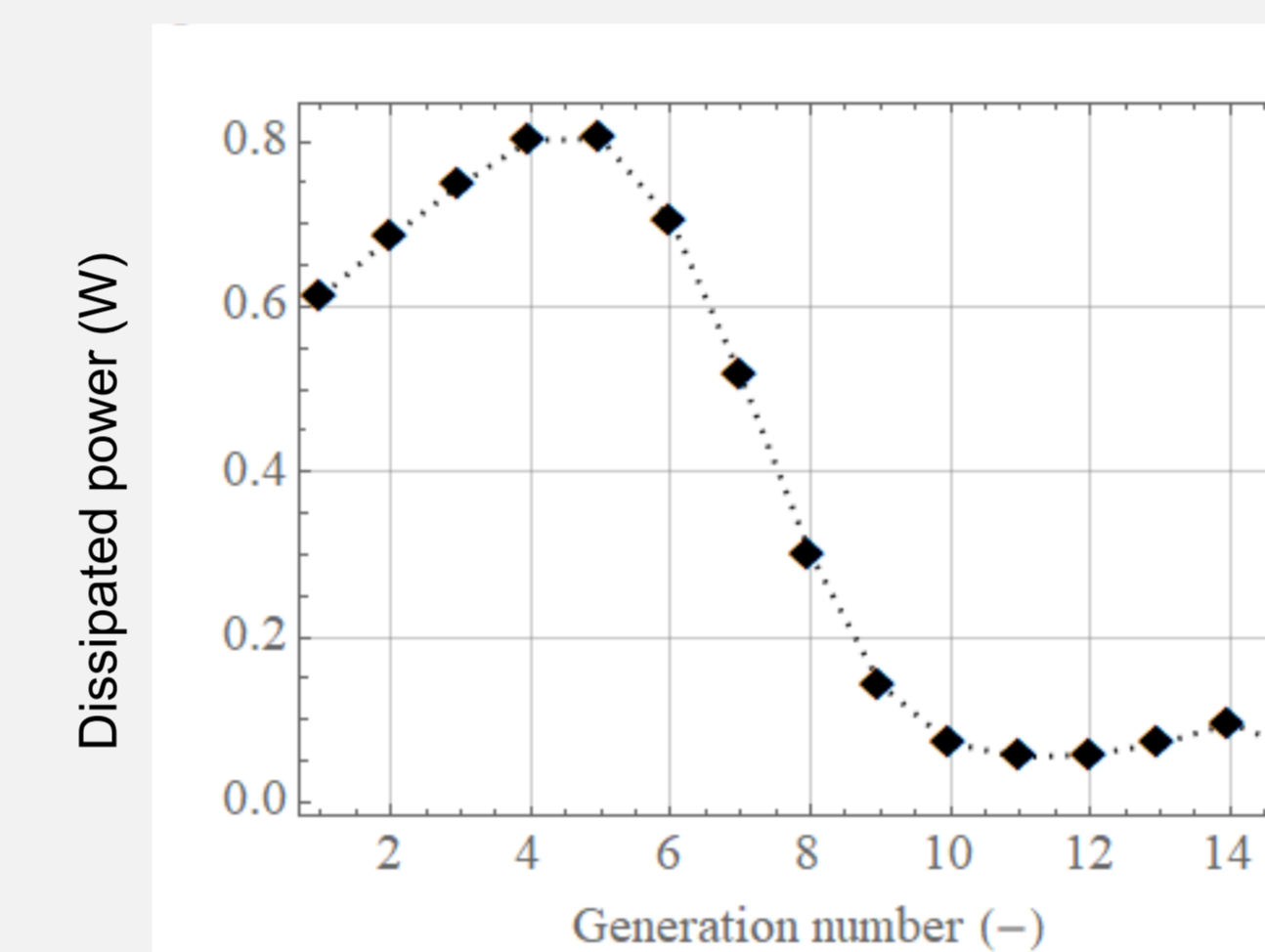
$$-\lambda_a \frac{\partial T}{\partial r} + \lambda_l \frac{\partial T_l}{\partial r} = \mathcal{L} D \frac{\partial C}{\partial r}$$

## Results

### At rest

Power loss is estimated to be around 5 W and water loss around 150 mL/day.

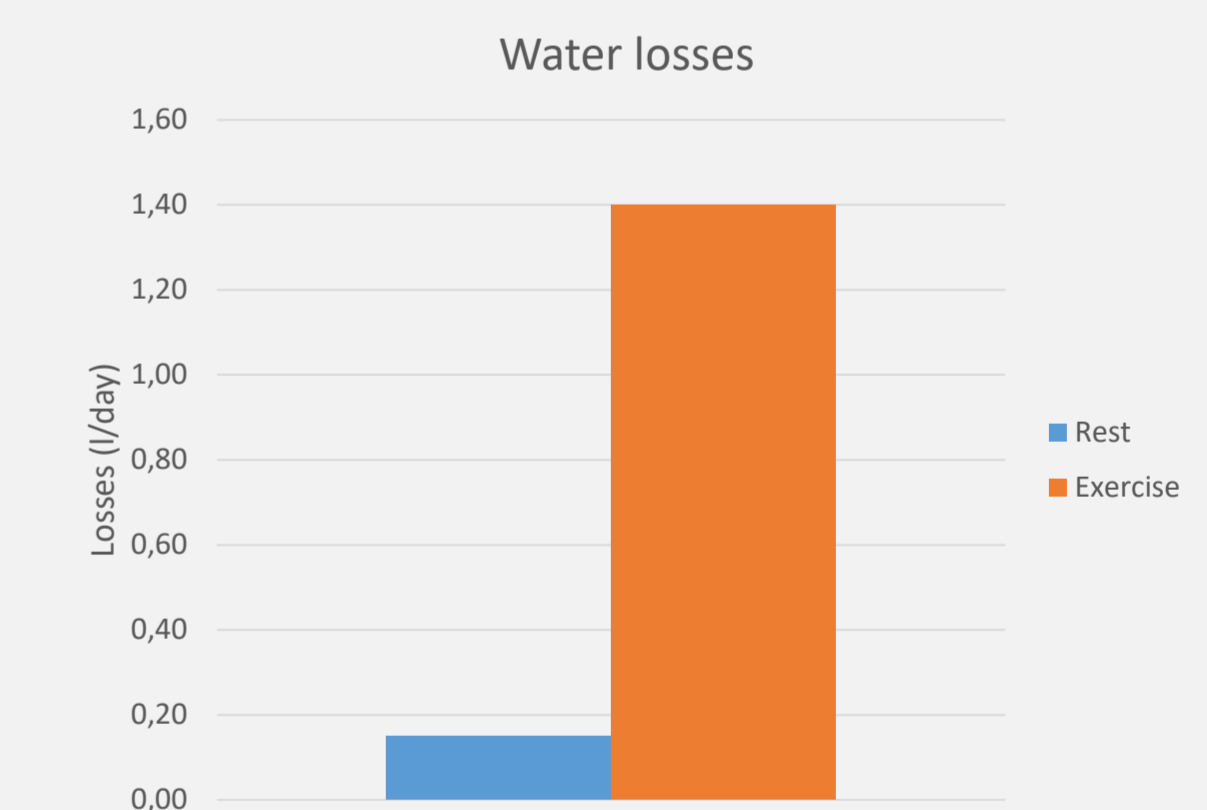
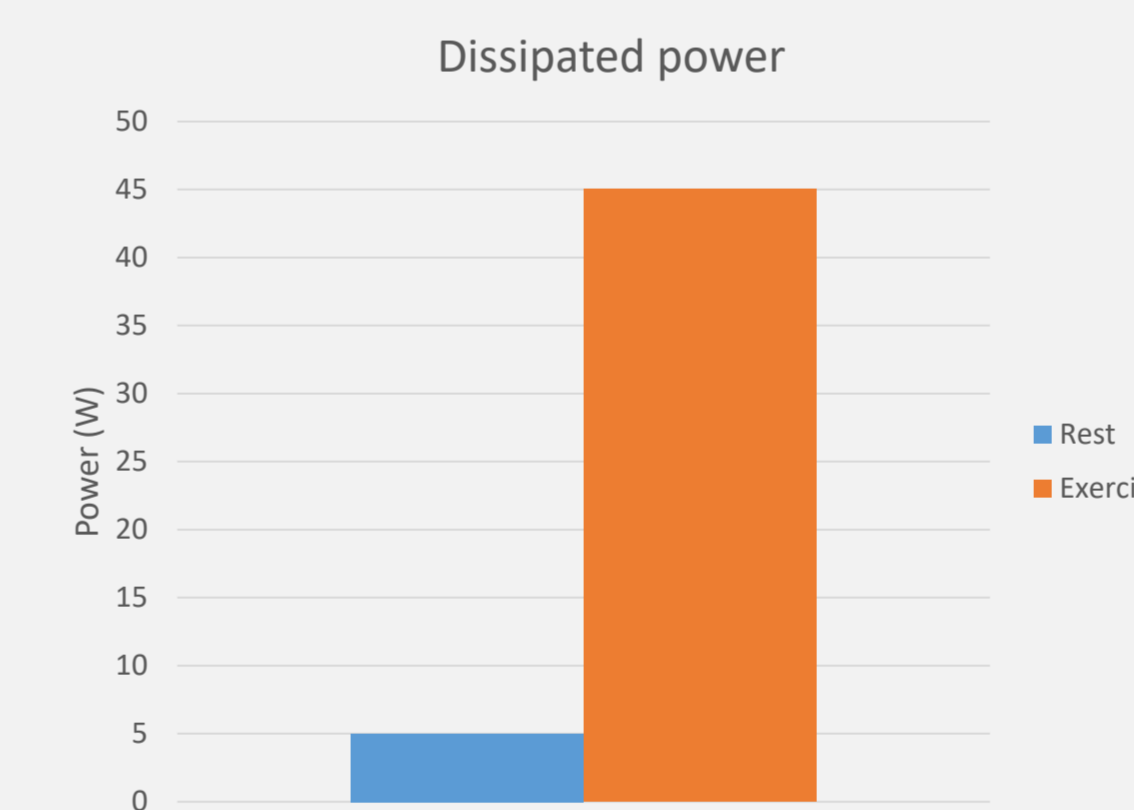
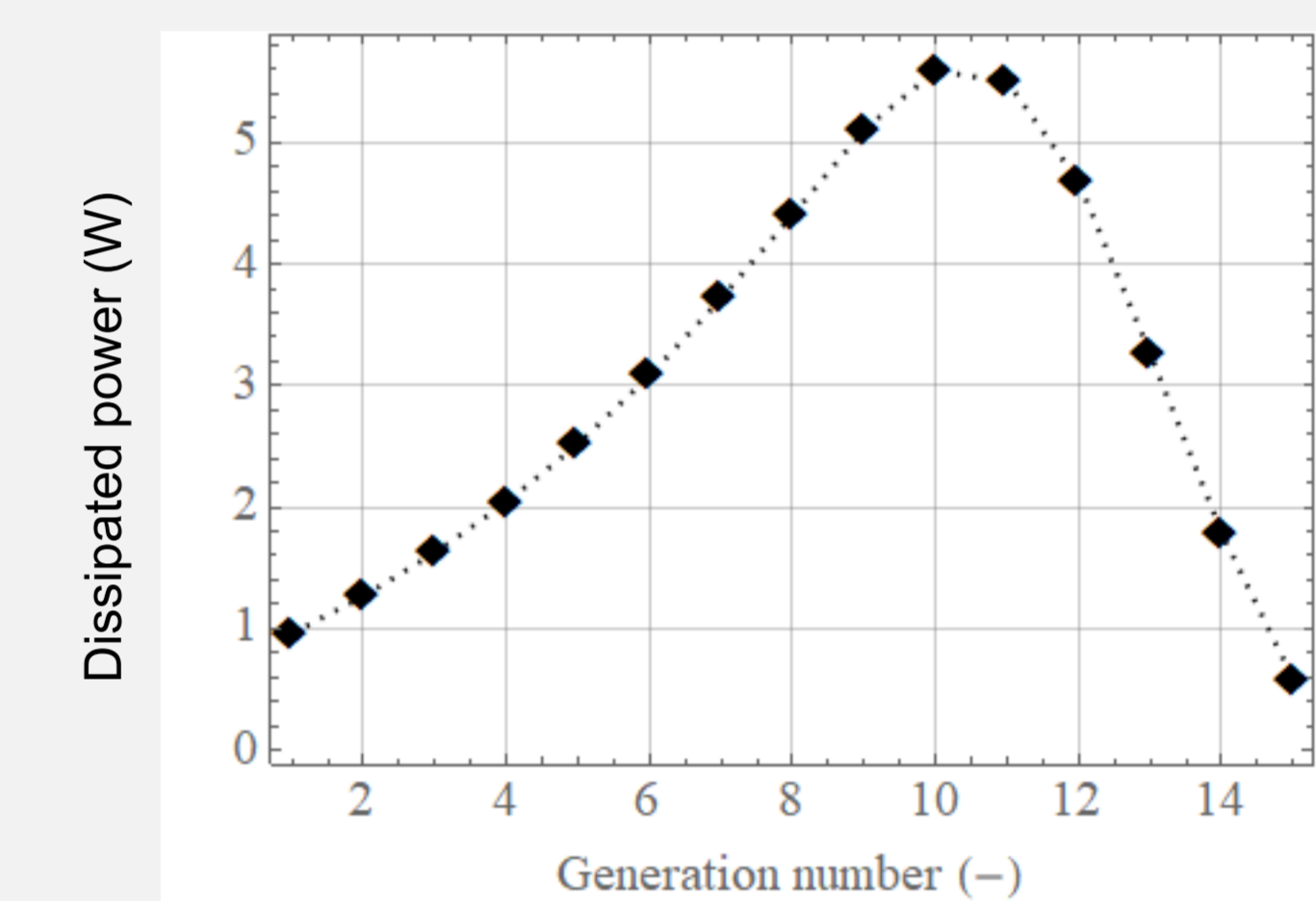
Air saturation occurs in generation 10; peak of heat dissipation in generation 4.



### During exercise

Power loss rises to 45 W and water loss is around 1.4 L/day.

Air saturation occurs in generation 15; peak of heat dissipation in generation 10.



## Discussion

The magnitude of thermal and hydric losses in the bronchi suggests that evaporation can modify the dynamics of bronchial mucus. This could influence its properties, such as its viscosity, which is critical in several pathologies, as in cystic fibrosis (CF). Body water and thermal balance are likely to be impacted too, especially during exercise.

## Conclusion

Our results confirm that bronchial evaporation is critical regarding mucus dynamics, and body water and thermal balance. They highlight the importance of inspired air conditions for the management of sensitive subjects, such as CF patients or athletes with exercise-induced asthma.