SUPPLEMENTARY MATERIAL

Drift of a drowning victim in rivers: conceptualization and global sensitivity analysis under idealized flow conditions

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A. Complement to the description of the methodology

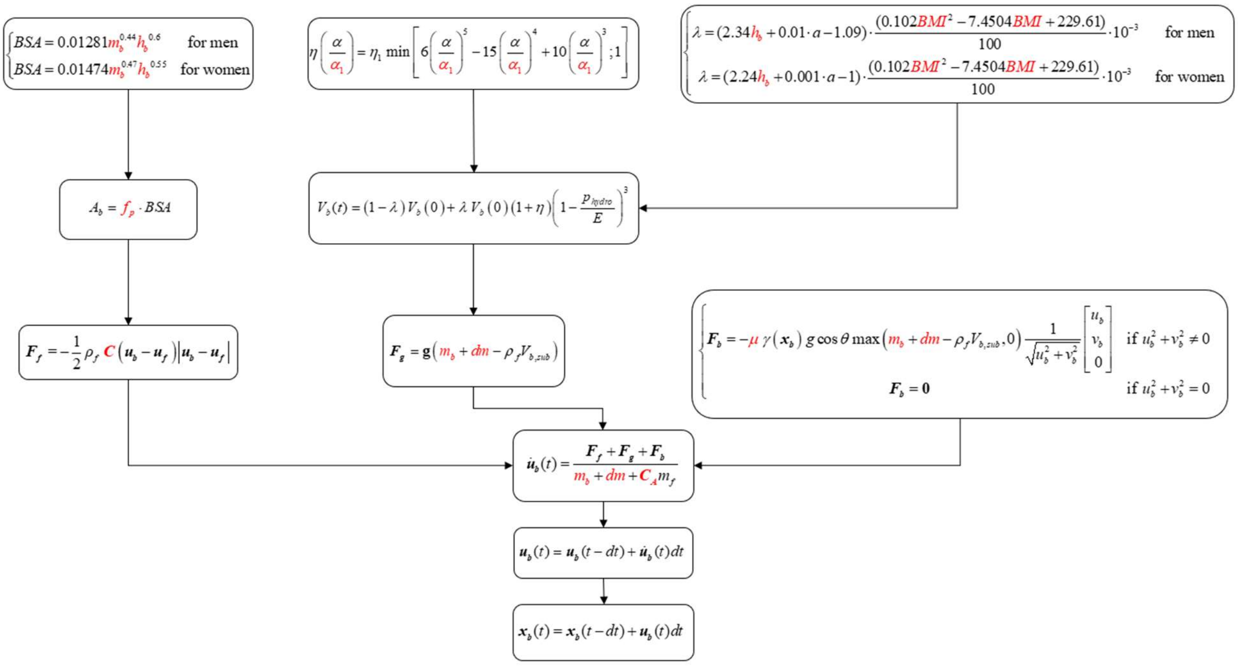


Figure S1: Workflow of equations used in the model.

B. Complements to model formulation

Function $\gamma(\boldsymbol{x}_\mathbf{b})$ is parametrized as follows (Figure S2):

$$\gamma(\mathbf{x_b}) = \begin{cases} \dfrac{1-\dfrac{z_b - b(x_b, y_b)}{\varepsilon_{max}} - \dfrac{\varepsilon_{min}}{\varepsilon_{\max}}}{\dfrac{z_b - b(x_b, y_b)}{\varepsilon_{max}} \quad 1-\dfrac{\varepsilon_{min}}{\varepsilon_{\max}}} & \text{if } b(x_b, y_b) + \varepsilon_{min} \le z_b \le b(x_b, y_b) + \varepsilon_{max} \\ 0 & \text{if } \; z_b \ge b(x_b, y_b) + \varepsilon_{max} \end{cases} \tag{S1}$$

It is assumed that when the distance between the bottom and the body centre of mass exceeds a threshold ε_{max}, the bottom friction ceases to influence the body motion. The value of ε_{max} differs from that of ε_{min} typically due to limbs hanging down.

The formulation of $\gamma(\boldsymbol{x}_b)$ was selected so that the effects of bottom friction on the body motion become significant only when the body is located close to the bottom, i.e., when the elevation z_b of the body centroid is close to the bottom elevation $b(x,y)$. This can be seen in Figure S2, which displays function

γ (horizontal axis) as a function of the distance of the body centroid to the river bottom (vertical axis). The value of γ remains small except in the vicinity of the bottom.

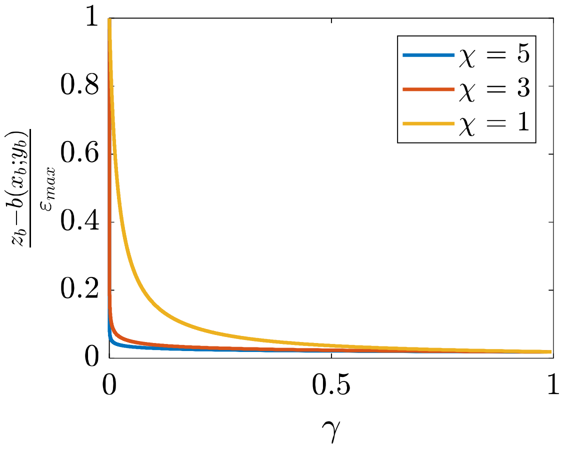


Figure S2: Shape of function $\gamma(\boldsymbol{x}_\mathbf{b})$ as a function of the distance between the body centre of mass and the bottom, $z_b - b(x_b, y_b)$, scaled by the length ε_{max}.

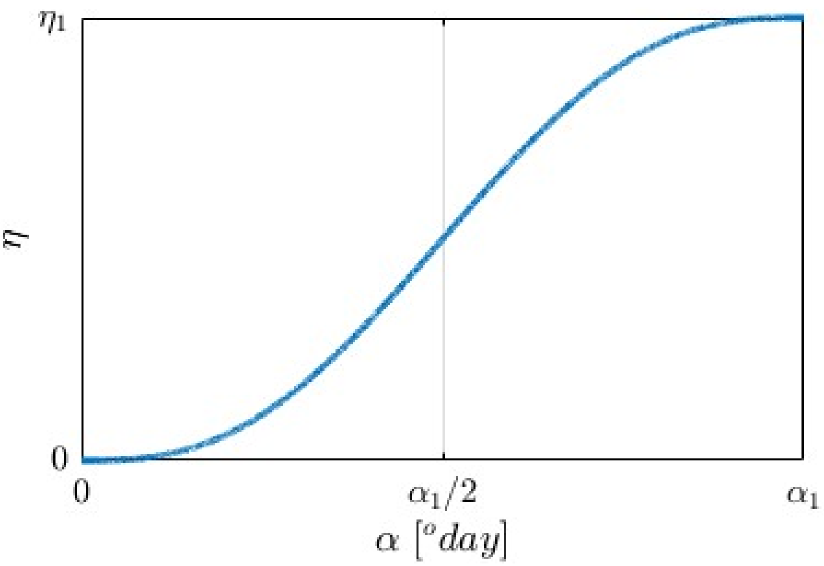


Figure S3: Functional relationship between the ADD, α, and the degree η of influence of body decomposition on body volume.

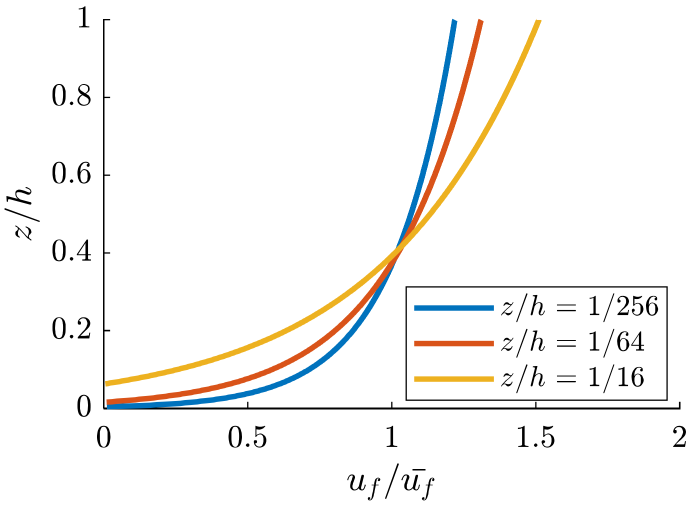


Figure S4: Flow velocity profile over the flow depth.

C. Empirical anthropometric closures

C.1 Estimation of the frontal area

Among the existing empirical relations for determining the body surface area (Mosteller, 1987; Du Bois and Du Bois, 1989; Tanabe et al., 2000; Tikuisis et al., 2001), we opted for the most recent one Tikuisis et al. (2001):

$$BSA = 0.01281 m_b^{0.44} h_b^{0.6} \quad [\text{m}^2] \qquad \text{for men} \tag{S2}$$

$$BSA = 0.01474 m_b^{0.47} h_b^{0.55} \quad [\text{m}^2] \qquad \text{for women} \tag{S3}$$

with m_b in kg and h_b in cm.

Following Tanabe et al. (2000), the frontal area may be approximated by multiplying the body surface area by a projection factor f_p which depends on the body positioning and orientation (pitch, yaw and roll angles):

$$A_b = f_p \cdot BSA \quad [\text{m}^2] \tag{S4}$$

Based on the work of Tanabe et al. (2000), a plausible range of values of the projection factor is given by [0.16; 0.36].

C.2 Estimation of the body initial volume

Three cases were distinguished for the estimation of the body initial volume, as detailed hereafter.

- If $BMI < 29$ kg/m² and $m_b < 85$ kg:

$$V_b(0) = (0.992 m_b + 0.701) \cdot 10^{-3} \quad [\text{m}^3] \tag{S5}$$

This formula is taken from a study by Liu et al. (2017), which is based on a sample of Chinese people (average mass of 65 kg, with a standard deviation of 7 kg). As such, Eq. (S5) is not adapted to taller people.

- If $BMI < 29$ kg/m² and $m_b \geq 85$ kg:

$$V_b(0) = BSA \cdot (51.44 \frac{m_b}{h_b} + 15.3) \quad [\text{m}^3] \tag{S6}$$

This formula is taken from Sendroy and Collison (1965).

- If $BMI \geq 29$ kg/m²:

$$V_b(0) = BSA \cdot (51.44 \frac{m_b}{h_b} + 15.3) \cdot 1.04 \quad [\text{m}^3] \tag{S7}$$

This equation reflects the tendency of people with a higher BMI to be generally more fat than muscled ($\rho_{fat} = 900$ kg/m³, while $\rho_{muscle} = 1100$ kg/m³).

C.3 Estimation of lungs functional residual capacity (FRC)

The lungs volume at FRC (in m³) was estimated here as a function of the gender, age *a* (in years), body height (in m) and BMI using results by Stocks and Quanjer (1995) and Abston et al. (2017) results:

$$\begin{cases} V_{lung,FRC} = (2.34h_b + 0.01 \cdot a - 1.09) \cdot \dfrac{(0.102BMI^2 - 7.4504BMI + 229.61)}{100} \cdot 10^{-3} & \text{for men} \\ V_{lung,FRC} = (2.24h_b + 0.001 \cdot a - 1) \cdot \dfrac{(0.102BMI^2 - 7.4504BMI + 229.61)}{100} \cdot 10^{-3} & \text{for women} \end{cases} \tag{S8}$$

C.4 Estimation of the total lung capacity (TLC)

The total lung capacity (TLC, in m³) was approximated here using formulae developed by Stocks and Quanjer (1995) and Abston et al. (2017), which involve the body height h_b (in mà) and the BMI:

$$\begin{cases} TLC = (7.99h_b - 7.08) \cdot \dfrac{(0.0403BMI^2 - 3.1049BMI + 149.58)}{100} \cdot 10^{-3} & \text{for men} \\ TLC = (6.6h_b - 5.79) \cdot \dfrac{(0.0403BMI^2 - 3.1049BMI + 149.58)}{100} \cdot 10^{-3} & \text{for women} \end{cases} \tag{S9}$$

A first approximation for the value of parameter η_1 in Eq. (8) was obtained as follows:

$$\eta_1 \approx \frac{TLC - FRC}{FRC} \tag{S10}$$

D. Statistical distributions

The beta distribution is a family of continuous probability distributions defined on the interval [0; 1]. The shape of the distribution is controlled by two parameters α and β, which take positive values and appear as exponents of the random variable in the probability density function (McDonald and Xu, 1995):

$$PDF(x,\alpha,\beta)=\frac{x^{\alpha-1}(1-x)^{\beta-1}}{B(\alpha,\beta)} \tag{S11}$$

with x in the range [0; 1] and $B(\alpha, \beta)$ defined as:

$$B(\alpha,\beta)=\frac{\Gamma(\alpha)\Gamma(\beta)}{\Gamma(\alpha+\beta)} \tag{S12}$$

with Γ the Gamma function.

Here, the distribution of a random variable X varying in an arbitrary range [X_1; X_2] was related to the random variable x as follows:

$$X=\left(X_2-X_1\right)x+X_1\,. \tag{S13}$$

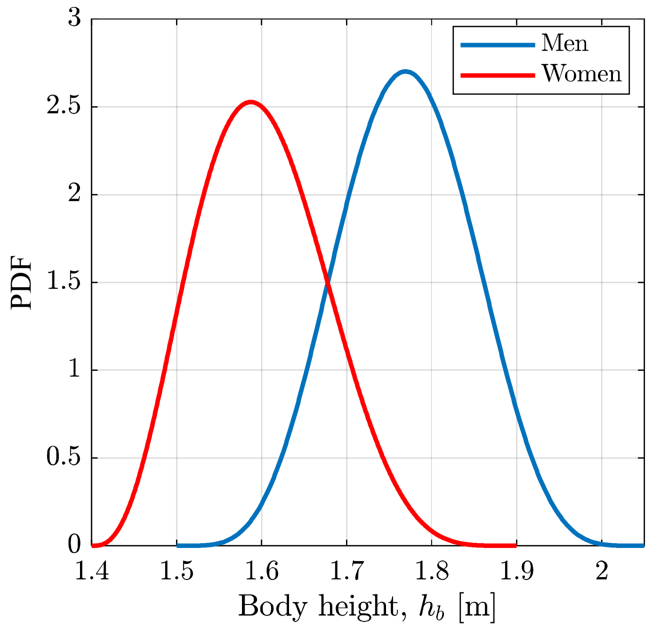


Figure S5: Beta distributions assumed for body height h_b in Scenario "unknown body" for men (α = 5.8697 and β = 6.075, in the range [1.5; 2.05] m) and for women (α = 3.976 and β = 5.965, in the range [1.4; 1.9] m) in Scenarios UB-LF and UB-HF.

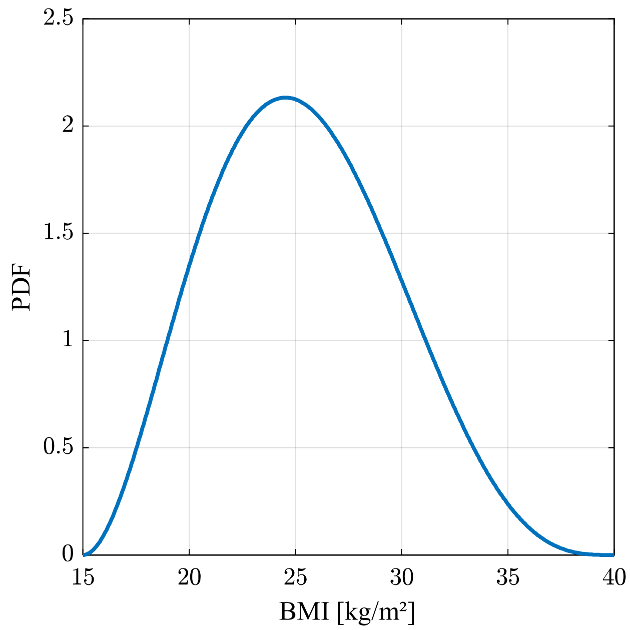


Figure S6: Beta distributions assumed for BMI for both genders (α = 3.0102 and β = 4.2628, in the range [15; 40] kg/m²) in Scenarios UB-LF and UB-HF.

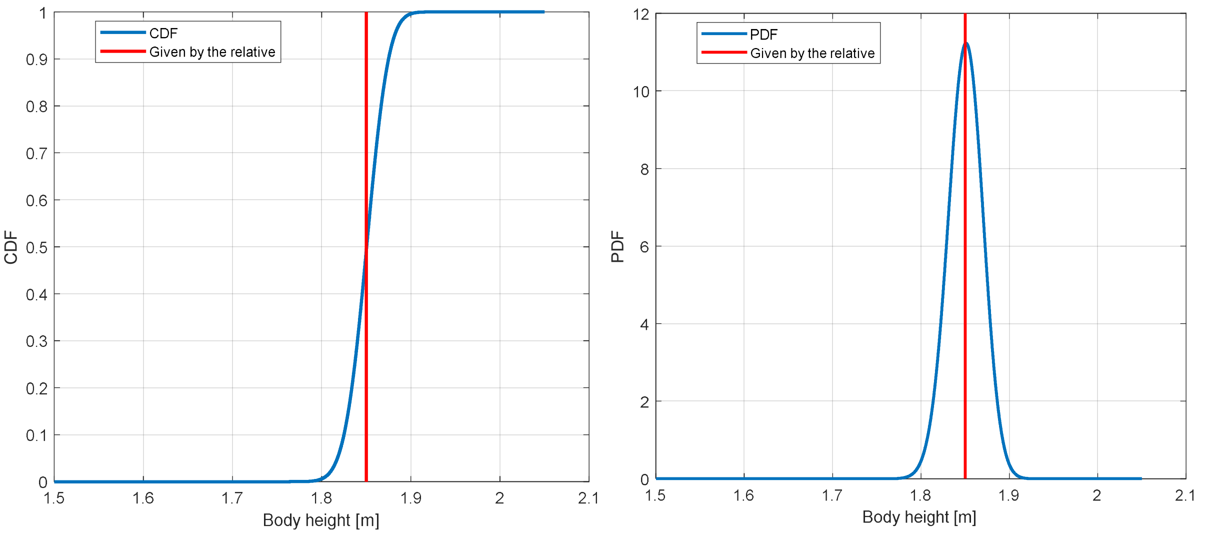


Figure S7: Cumulative distribution function and probability density function of a beta distribution for h_b of a victim with a mode of 1.85 m and a difference between the mode and the percentiles 10 and 90 of 0.025 m (Scenarios KB-LF and KB-HF).

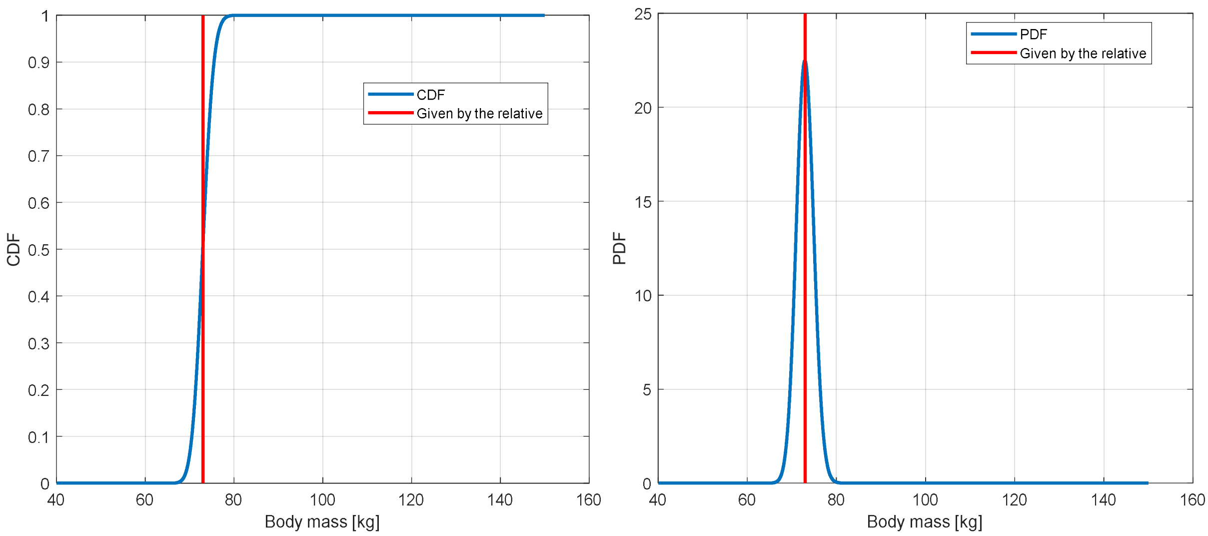


Figure S8: Cumulative distribution function and probability density function of a beta distribution for the mass m_b of a victim with a mode of 73 kg and a difference between the mode and the percentiles 10 and 90 of 2.5 kg (Scenarios KB-LF and KB-HF).

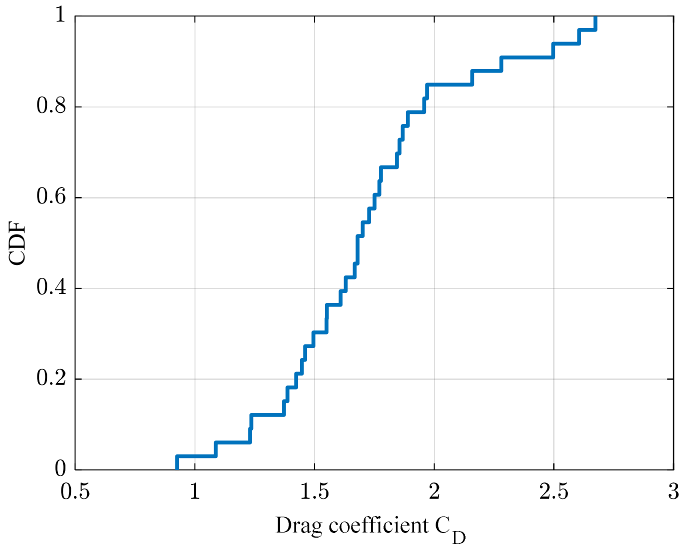


Figure S9: Empirical cumulative density function (CDF) of observed drag coefficient of a human-like body obtained from laboratory experiments (in a hydraulic flume) involving reduced-scale dummies, i.e., dummies which are about six times smaller than a typical human body (Delhez et al., 2021).

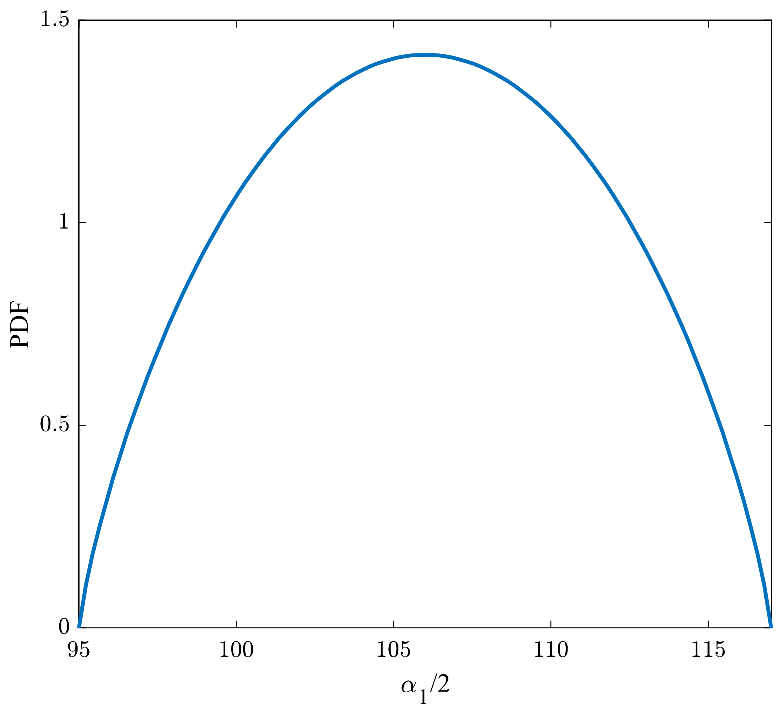
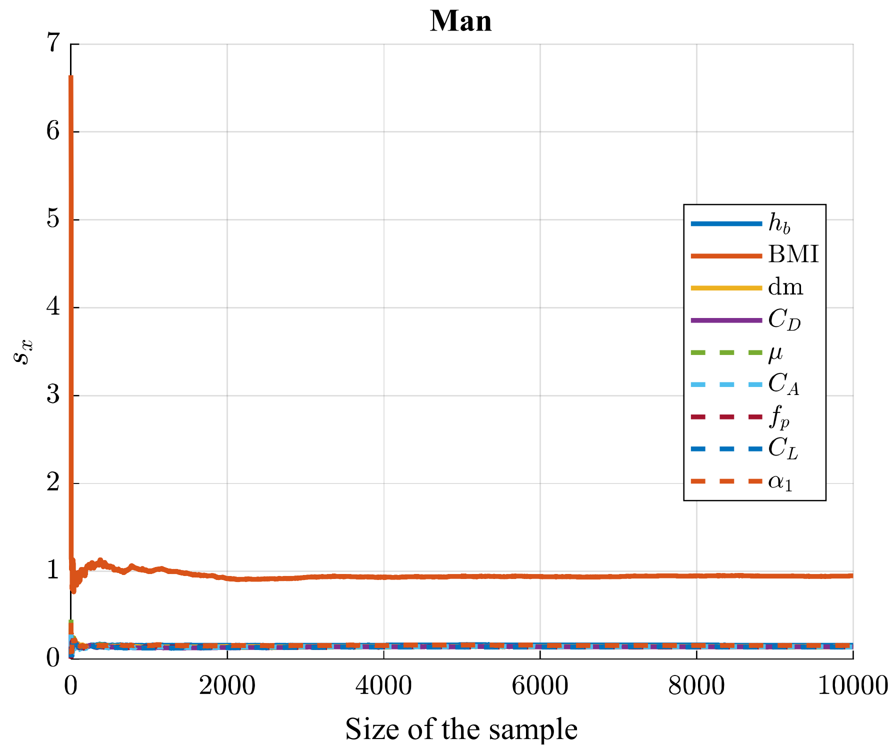
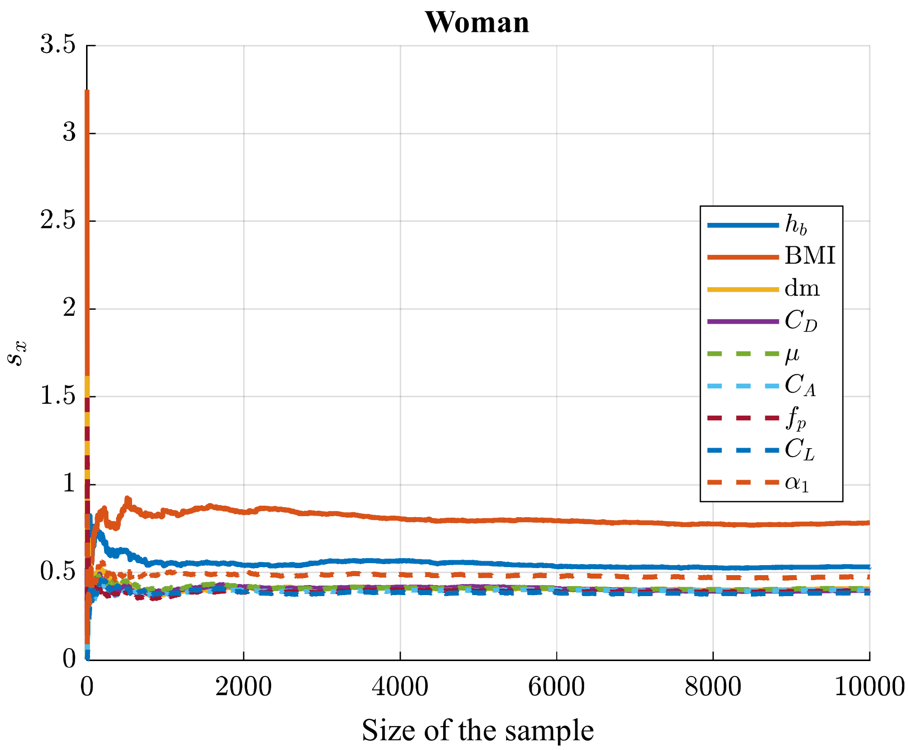


Figure S10: Beta distribution considered for α_1 / 2, with parameters $\alpha = \beta = 1.8024$.

E. Convergence analysis in the most critical case



(a)



(b)

Figure S11: Sobol' index as a function of the number of runs for the case UB-HF

F. Bodies streamwise positions

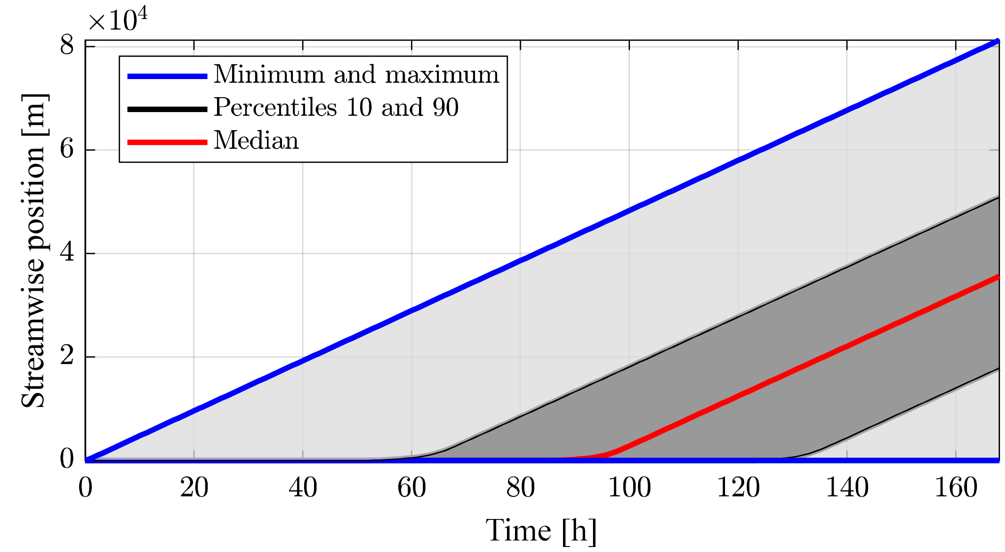


Figure S12: Scenario UB-LF

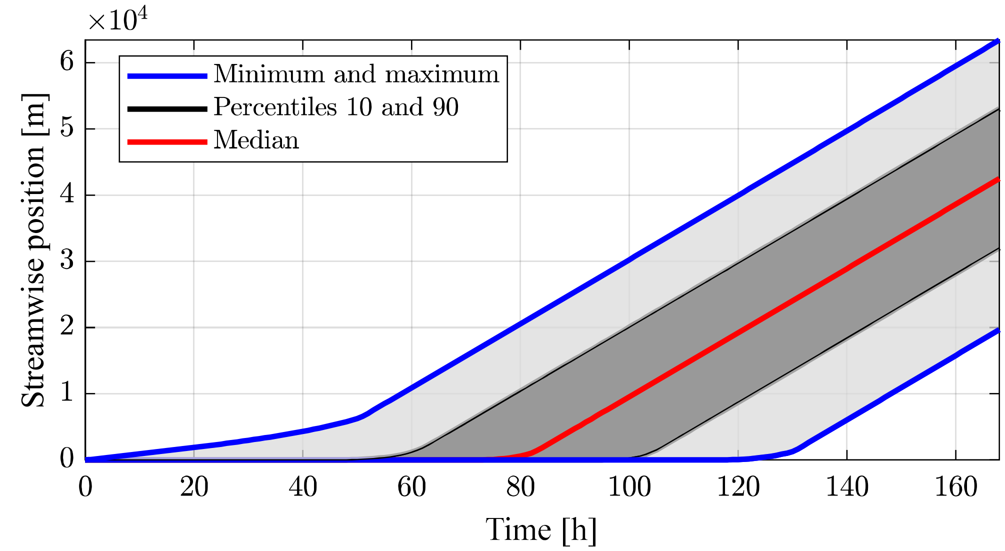


Figure S13: Scenario KB-LF

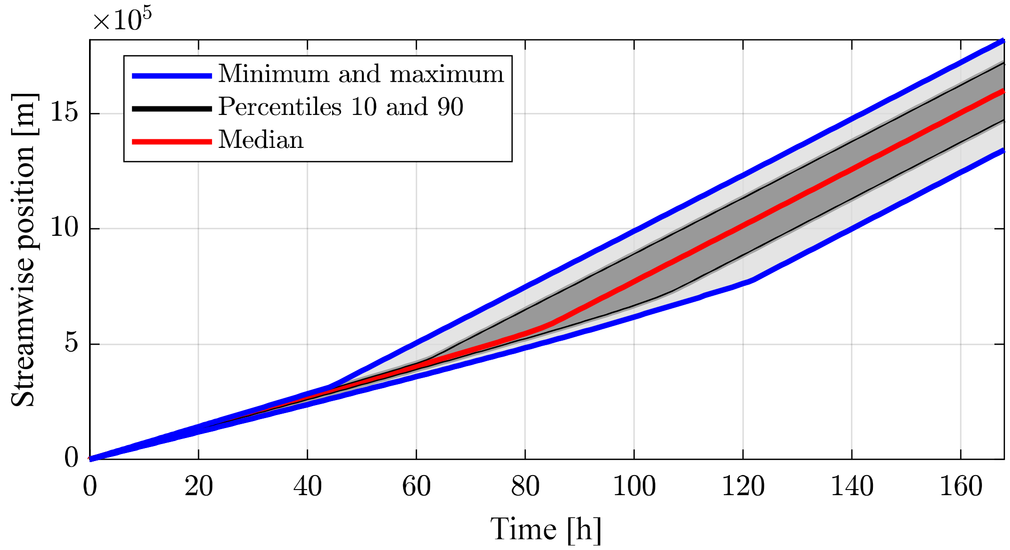


Figure S14: Scenario KB-HF

G. Sobol' index for grouped parameters without decomposition and for HF scenarios

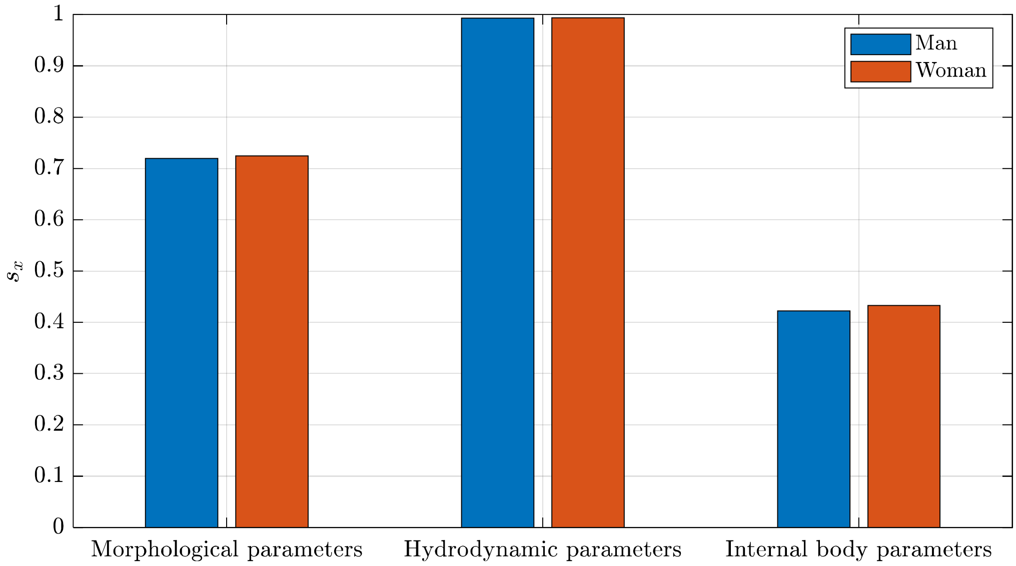


Figure S15: Without vertical motion, Scenario UB-HF

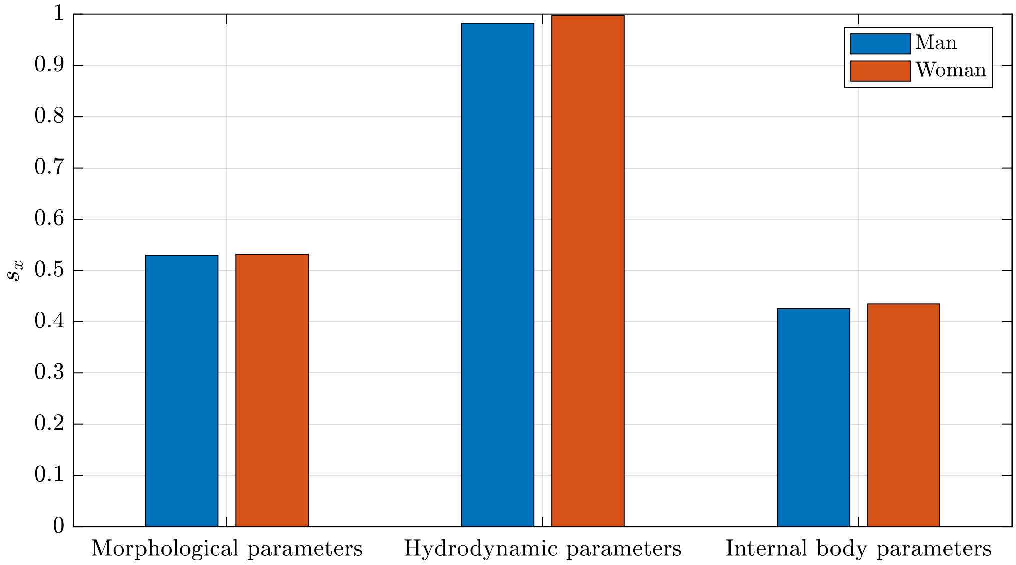


Figure S16: Without vertical motion, Scenario KB-HF

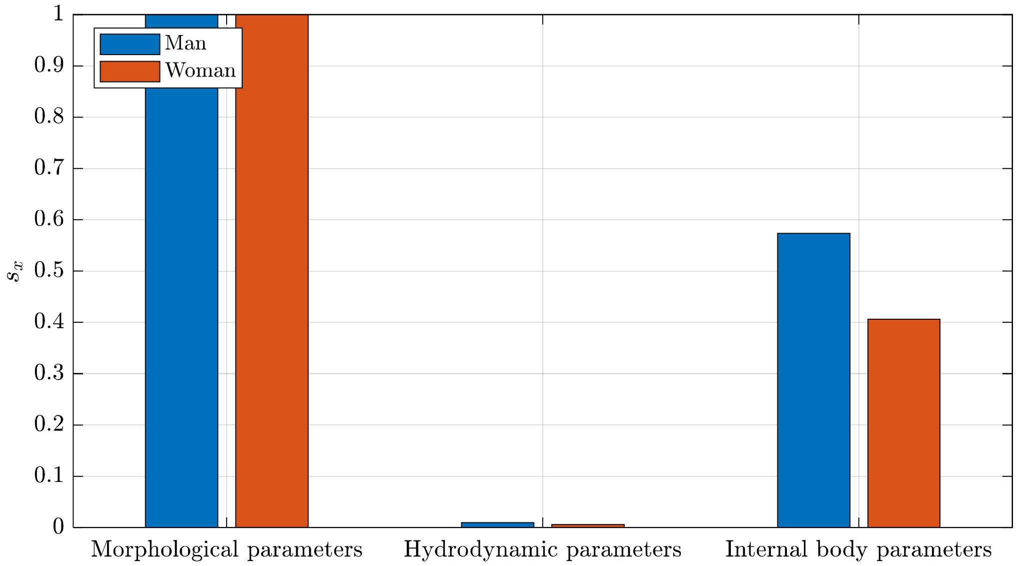


Figure S17: Without decomposition, Scenario UB-LF

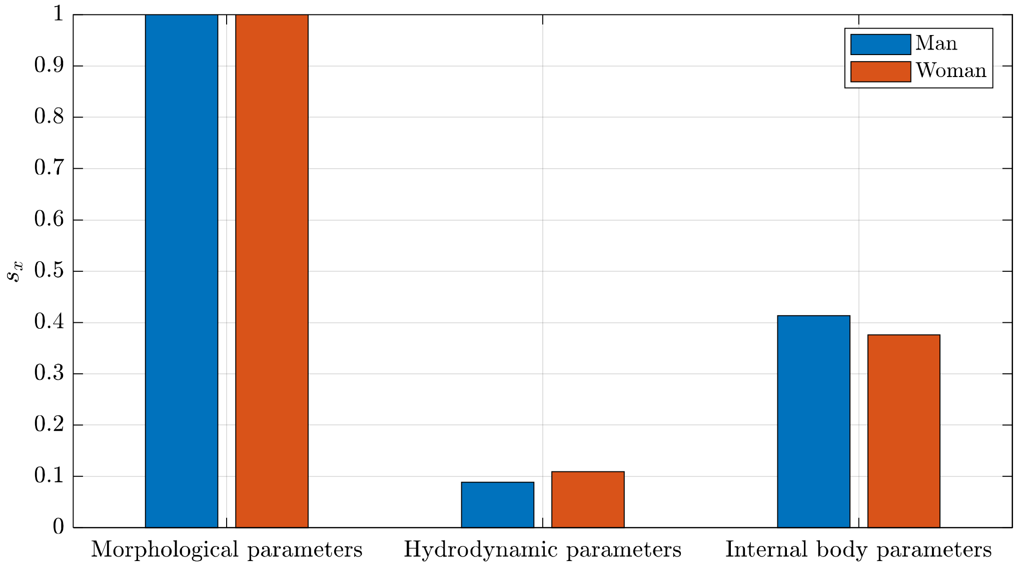


Figure S18: Without decomposition, Scenario UB-HF

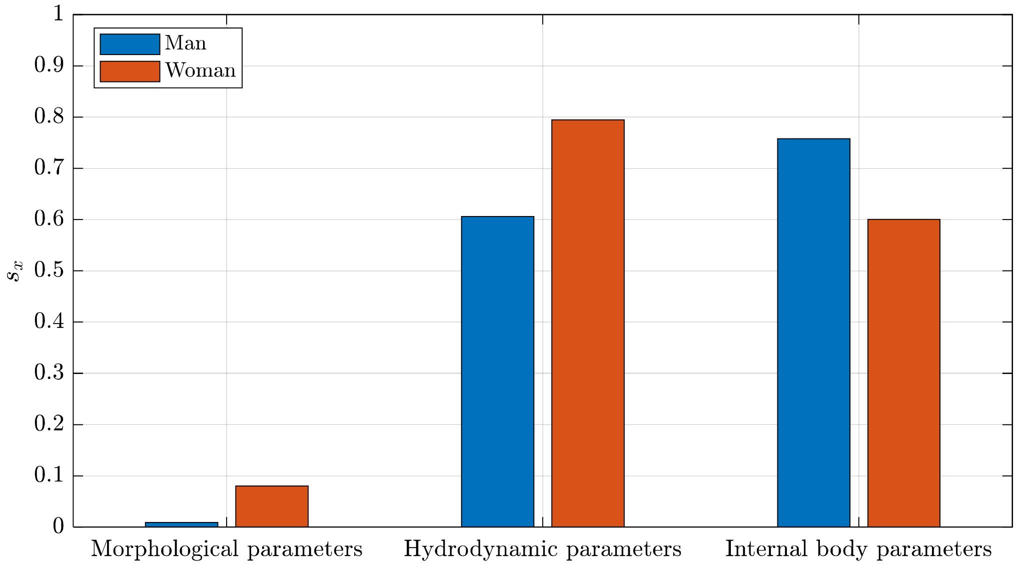


Figure S19: Without decomposition, Scenario KB-LF

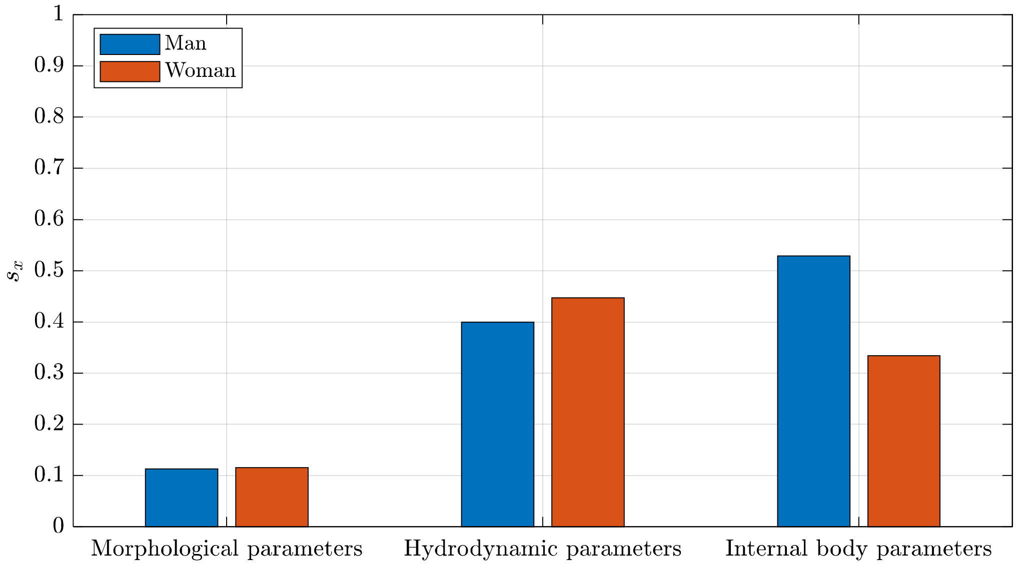


Figure S20: Without decomposition, Scenario KB-HF

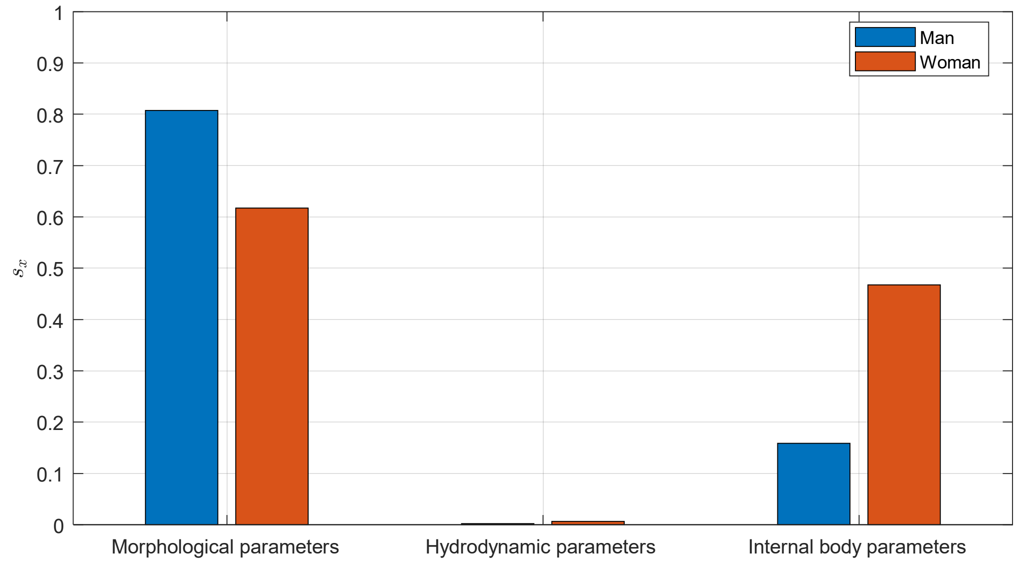


Figure S21: Classic drowning, Scenario UB-HF

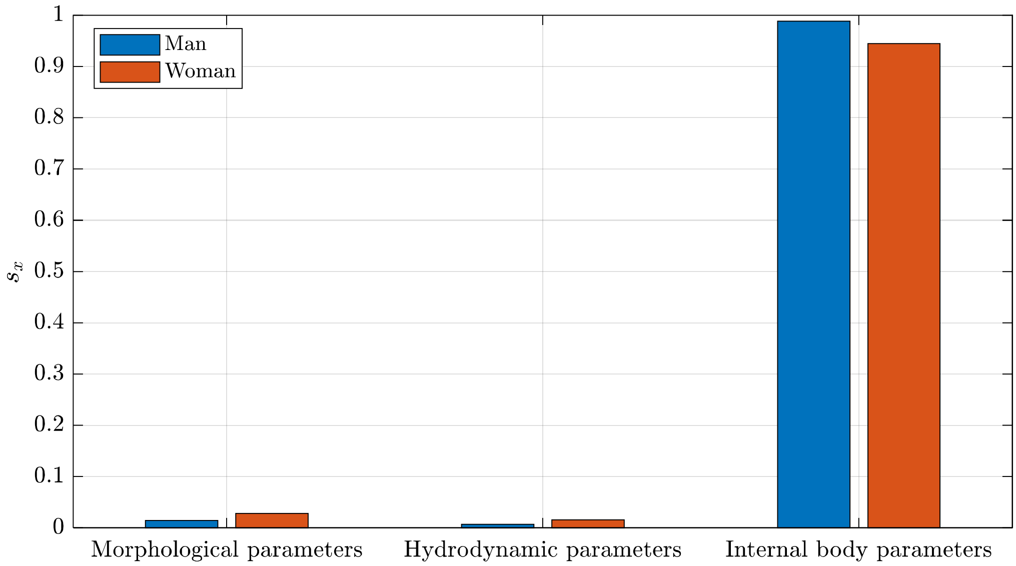


Figure S22: Classic drowning, Scenario KB-HF

References

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