# Modeling the relationship between training and performance: alternatives to the impulse-response model


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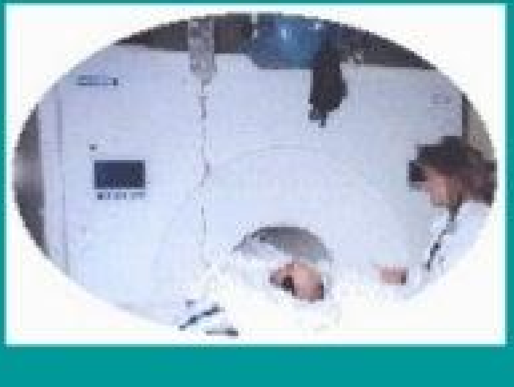
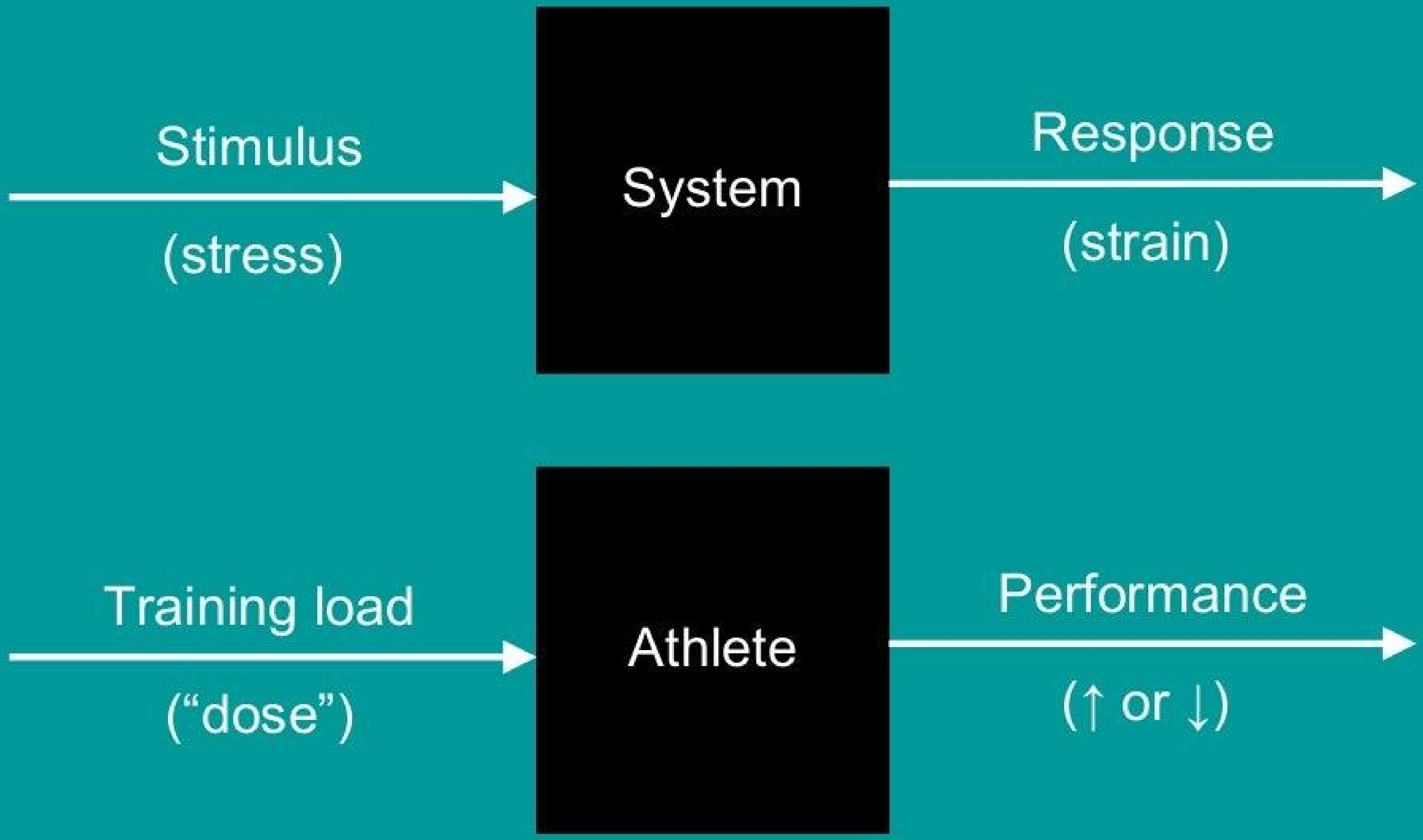


# The relationship between training and performance



# Why attempt to mathematically model the relationship between training and performance?

1) To obtain greater insight or understanding of this relationship, confirm existing hypotheses or generate new ones, etc.

2) To develop a practical tool that can be used by coaches and/or athletes to improve performance.

# Different types of mathematical models

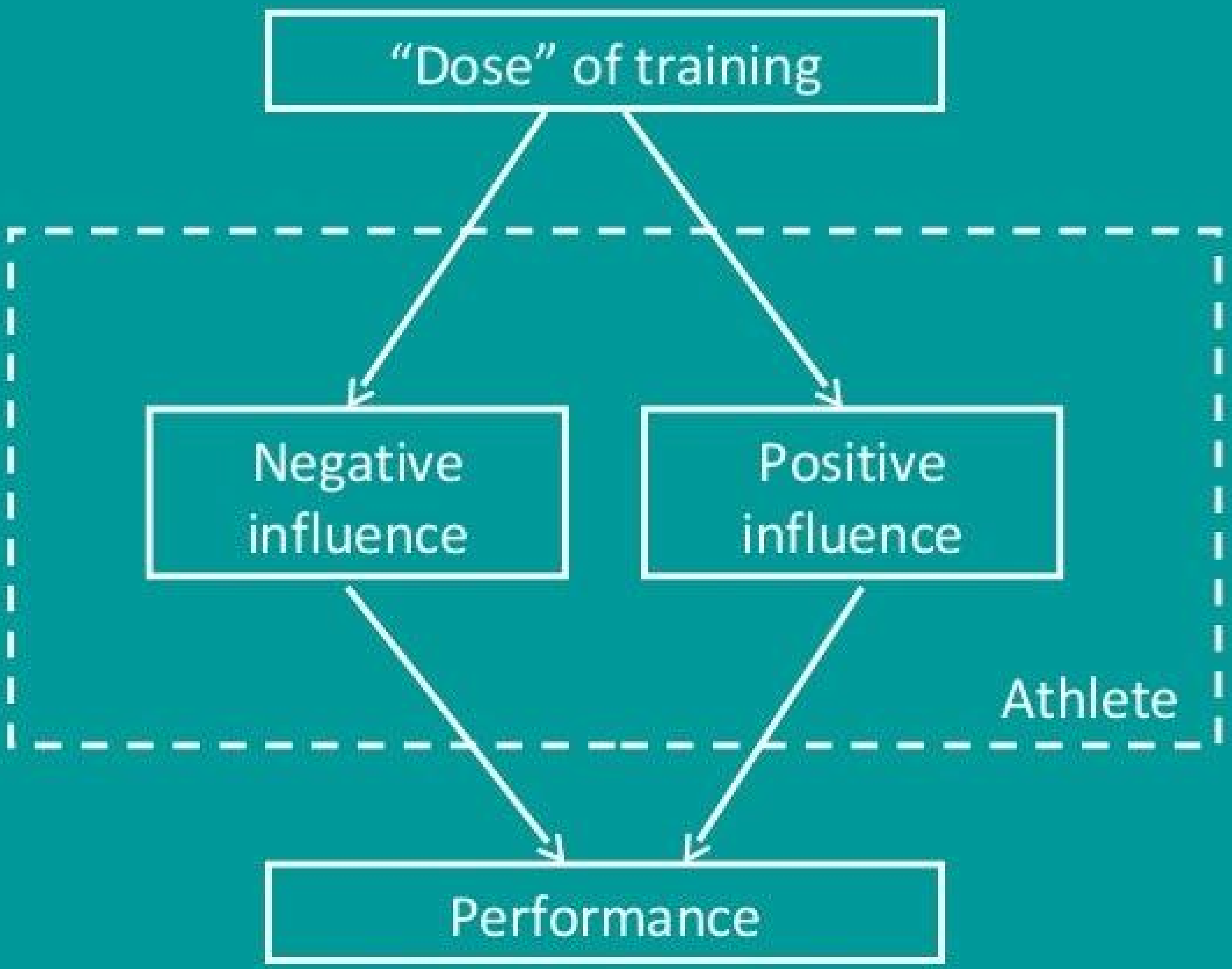
1) “Bottom up“ models that are purely empirical in nature but are mathematically “pure”.

2) “Top down” models that attempt to take advantage of other available data to construct a more realistic and/or accurate model.

# An important caveat with respect to mathematical models

Mathematical models are artificial constructs that may, or may not, have any basis in reality.

# Banister's impulse-response model



# Banister's impulse-response model

$$p_t = p_0 + k_a \sum_{s=0}^{t-1} e^{-(t-s)/\tau_a} w_s - k_f \sum_{s=0}^{t-1} e^{-(t-s)/\tau_f} w_s$$

Where: $p_0$ = initial performance

$k_a$ = weighting factor for positive (adaptive) influence

$\tau_a$ = time constant for positive (adaptive) influence

$k_f$ = weighting factor for negative (fatigue) influence

$\tau_f$ = time constant for negative (fatigue) influence

$w_s$ = daily "dose" of training

# Prediction of training-induced changes in performance using impulse-response model

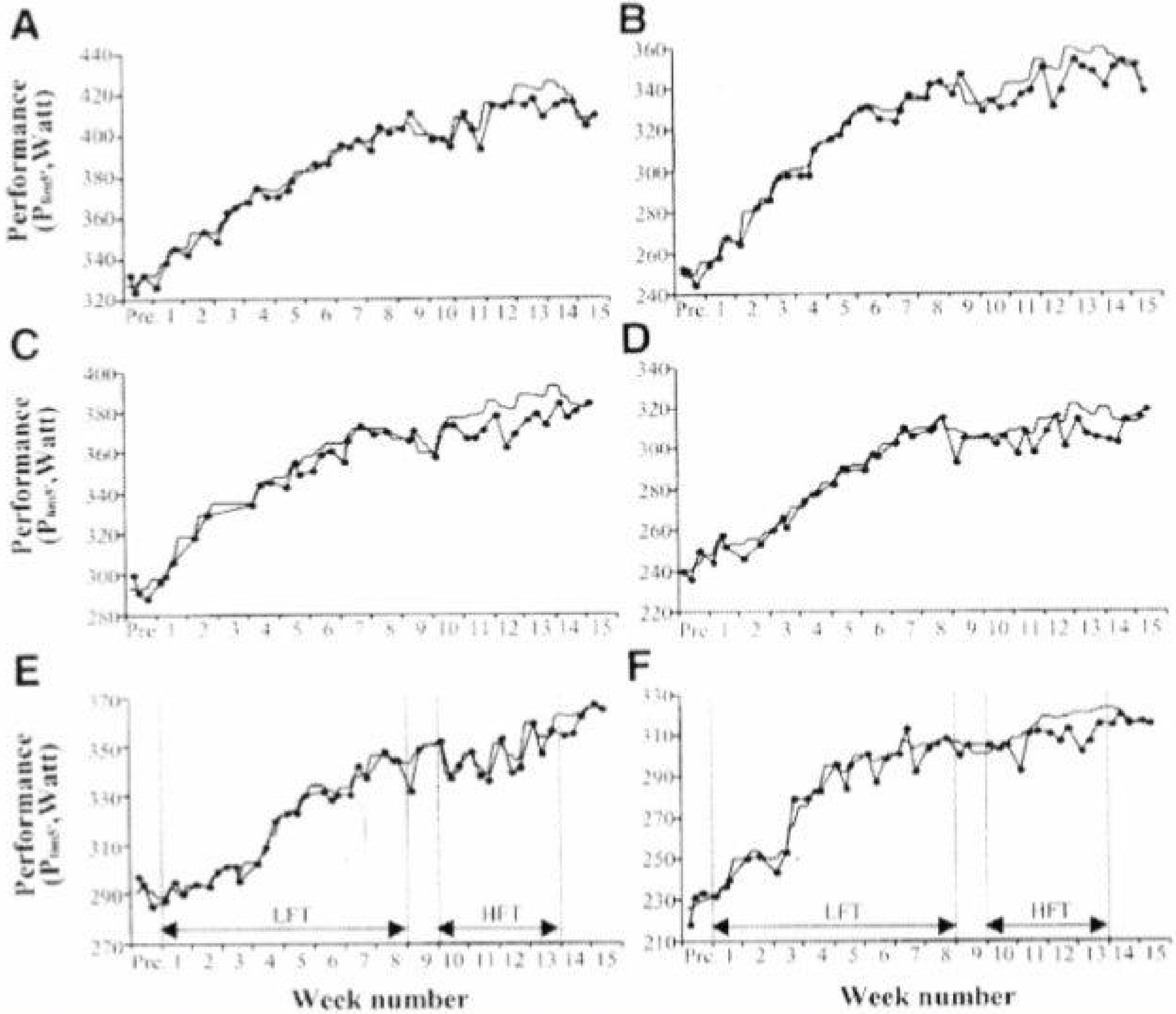



Fig. 2. Performance fit for the model with gain terms and time constants free to vary over time. *A–F*: *subjects 1–6*, respectively. $P_{lim5'}$, maximal power sustained for 5 min; Pre, before training; LFT, low-frequency training; HFT, high-frequency training.

Busso et al., *J Appl Physiol* 92:572, 2002

# Practical limitations of the impulse-response model

1) Obtaining a statistically-valid solution to the model requires large amounts of data (i.e., 5-50 measurements per adjustable parameter, or 20-200 in total).

2) Since the model parameters can change over time and/or with training, such measurements must be obtained in a fairly short period of time (i.e., within a 60-90 d “window”).

3) The performance measurements used to solve the model must be reflective of the demands of the actual event.

4) Even when conditions 1-3 are met, the accuracy of any future predictions may not be sufficient to be of any real value in guiding training.

# Conceptual limitations of the impulse-response model

1) The structure of the model is not based upon any known training-induced physiological adaptations and/or their known time courses.

2) The impulse-response model assumes a direct, linear relationship between training and performance (i.e., “more is ***always*** more”).

3) The impulse-response model is a ***static*** representation of a constantly ***adapting*** (i.e., dynamically-varying) organism, i.e., the athlete.

# Given the limitations of the impulse-response model, what’s a person to do?!?

1) Simply ignore the research that has been performed using this method (i.e., the “ostrich approach”).

2) Attempt to apply the lessons learned from this research, even if you can’t actually use the model, i.e., “take the good, leave the bad” (e.g., the Performance Manager).

3) Look for an alternative to the impulse-response model.

# Alternatives to the impulse-response model that have been described in the scientific literature

1) Multiple regression/mixed linear modeling

2) Neural networking

3) Performance Potential meta-model (PerPot)

# Multiple regression/mixed linear modeling

Basis:

- Least-squares solution to model of the form:

  $Y_i = X_i\beta + Z_i b_i + \varepsilon_i$

Advantages:

- Math is relatively straightforward
- Random (individual) and fixed (population) effects included
- Non-linear effects can be modeled
- Data requirements are reasonable (i.e., n=20 observations)

Disadvantages:

- Predictive ability has generally been rather poor (i.e., $R^2 = \sim 0.4$)

# Example of mixed linear modeling of the performance of swimmers

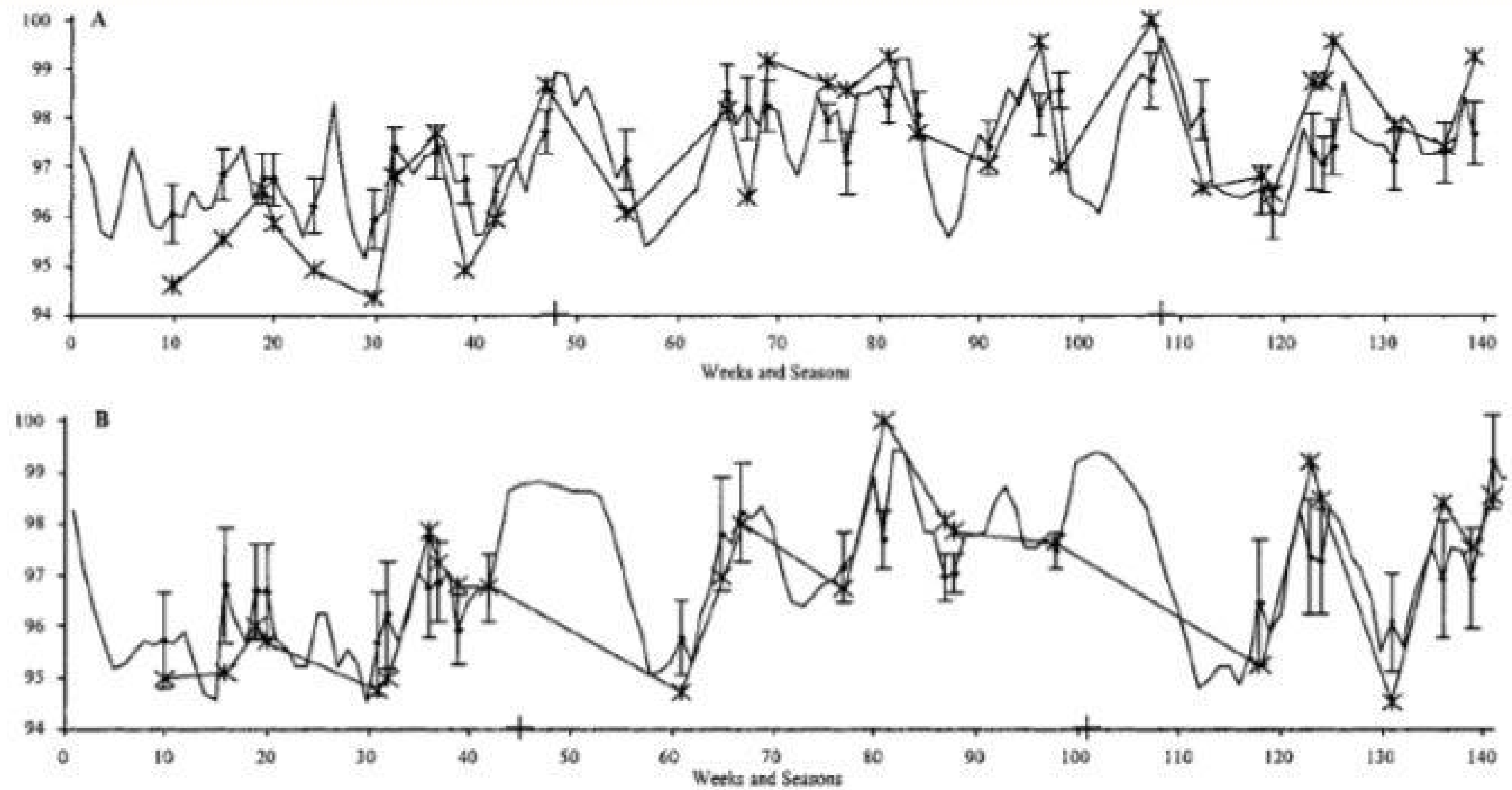
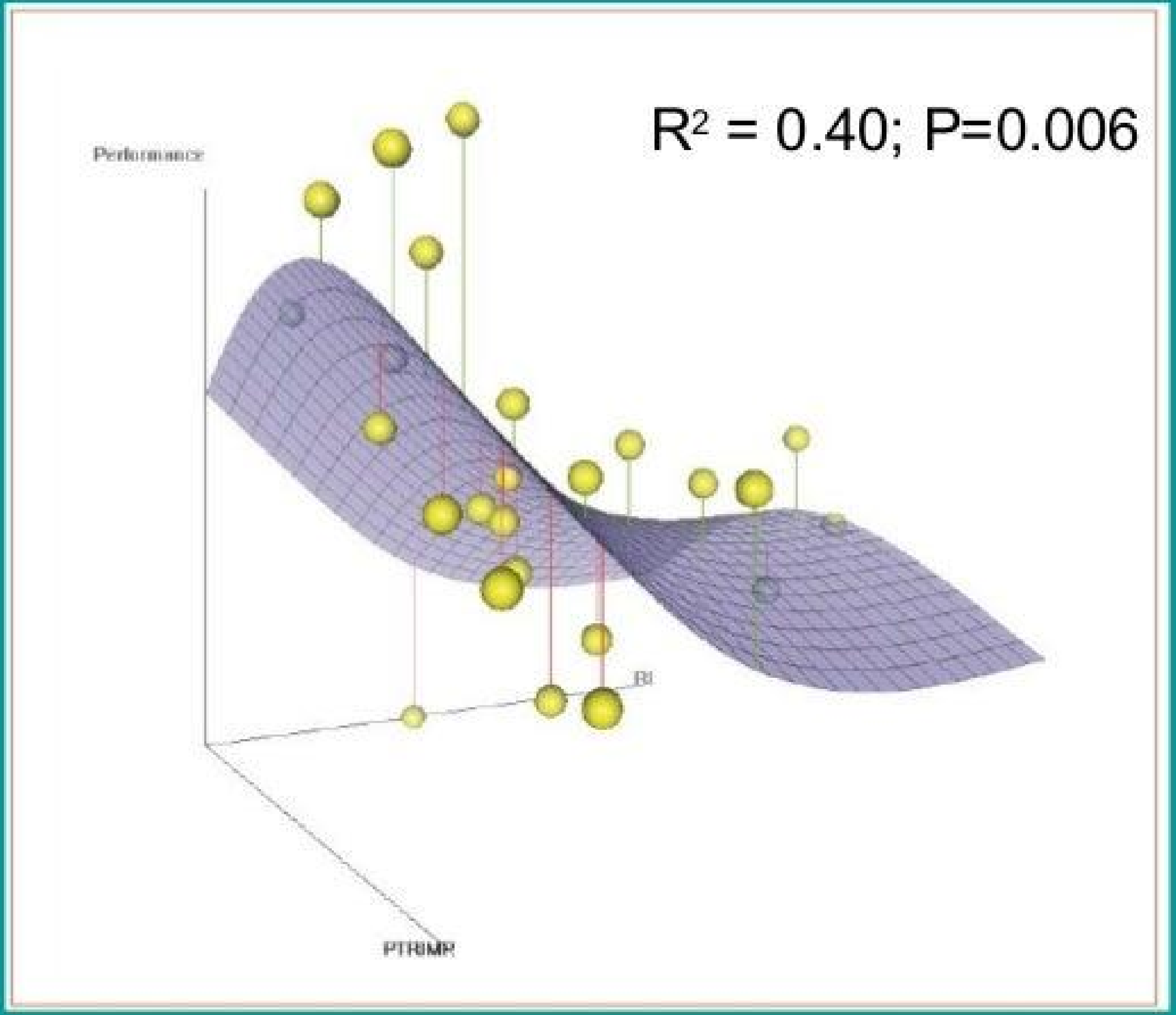



FIGURE 3—Real and modeled performance for subject 1 (A) and subject 7 (B). Performance in vertical axis is expressed in percent of the personal record. Time in horizontal axis is expressed in weeks and seasons (crosses separate first from second and second from third seasons). Real performance is indicated with stars linked by straight lines. Modeled performance is indicated by an irregular prediction curve and by diamonds for weeks where an actual performance took place. The 95% confidence intervals for the last case are also represented. For subject 1, the pattern of modeled performance is similar to that of real performance. Inversely, for subject 7, optimal modeled performance was situated shortly after the main seasonal competition, corresponding to the last event of the first and second season (weeks 40 and 98), indicating probably the need of a longer recovery.

Avalos, Hellard, and Chatard, 2003

# Example of multiple regression modeling of the performance of a professional cyclist




Churchill, 2009

# Neural networking

Basis:

- Relationship between training and performance is modeled using an interconnected series of “neurons”

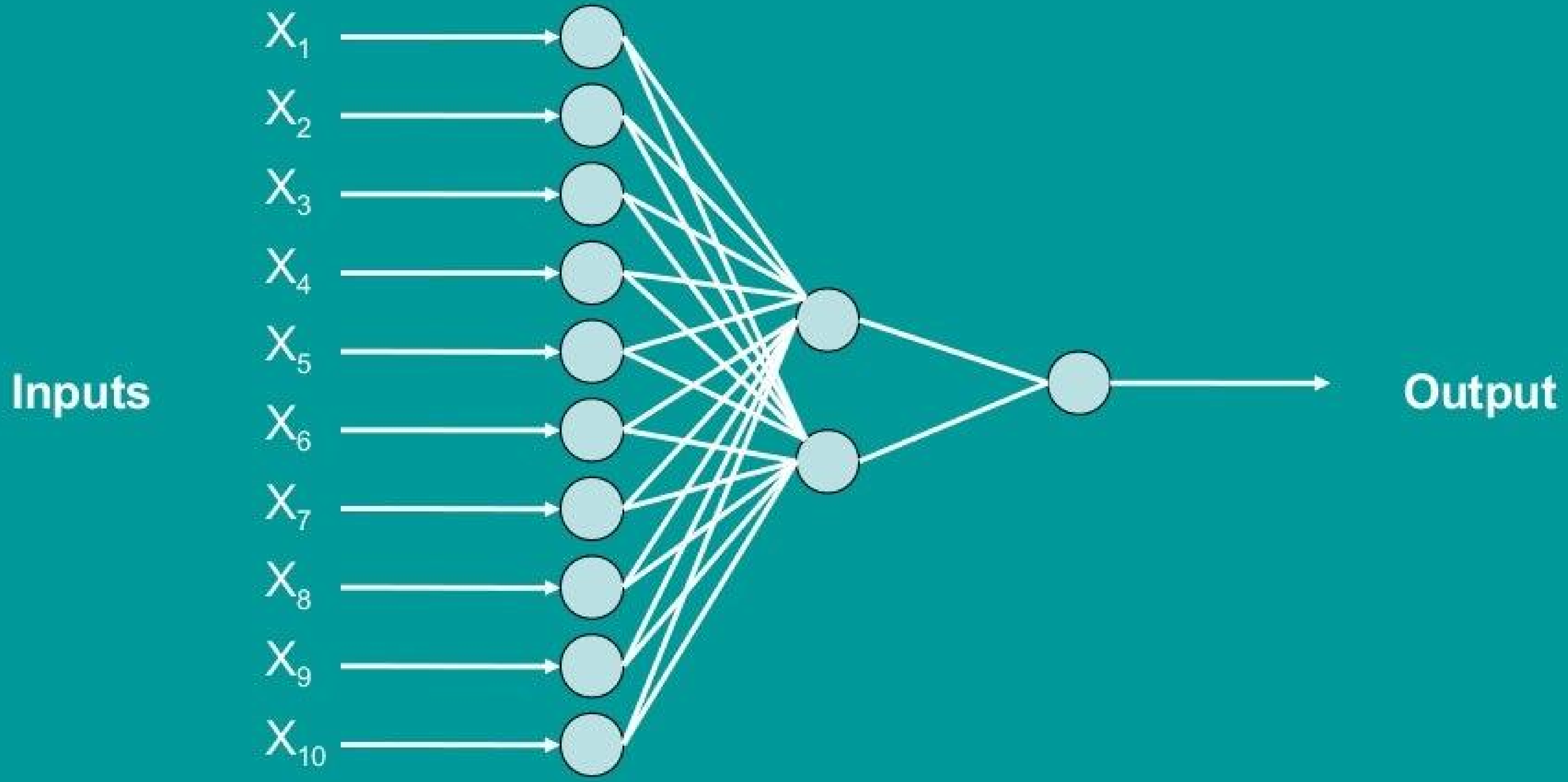
Advantages:

- No assumptions needed
- Complex, non-linear behavior can be modeled
- Accurate

Disadvantages:

- Large amounts of data are required to “train” network
- Provides no insight into underlying mechanisms

# Example of neural network with 10 input neurons, two hidden neurons, and one output neuron



# Example of neural network modeling of the performance of young swimmers (n=138)

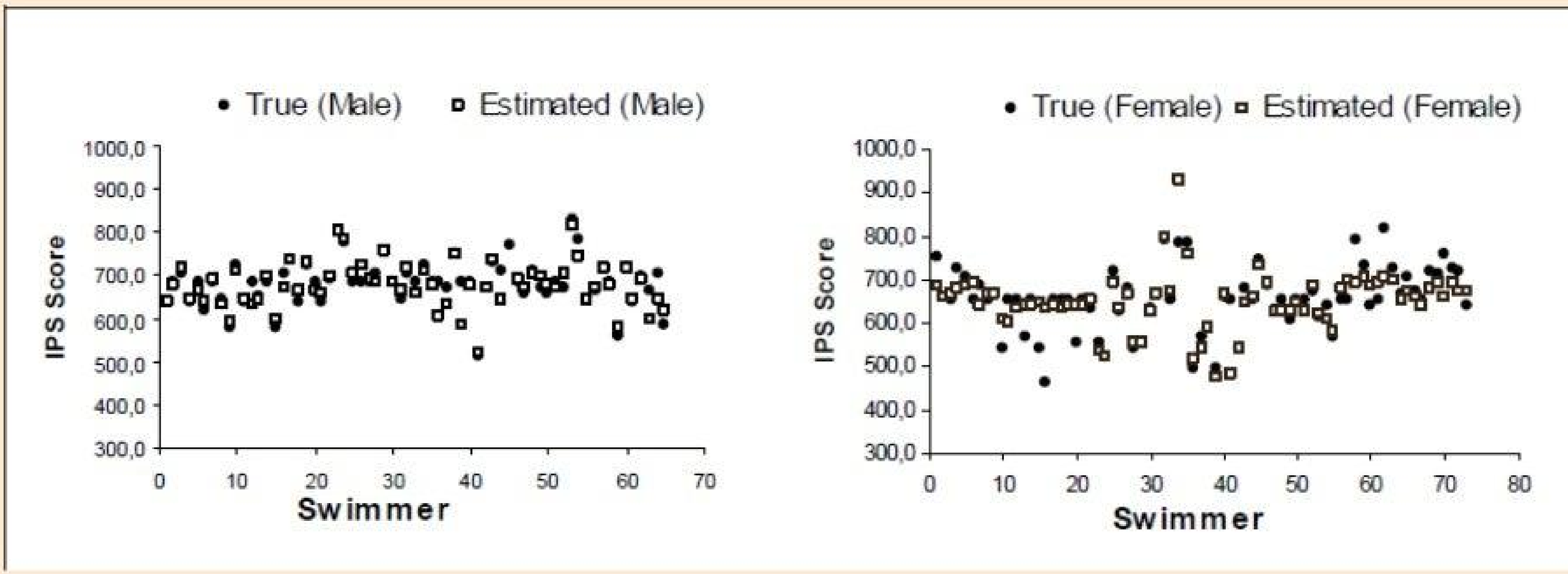



**Figure 2.** Model estimation to the 400 meters FC event for male (left) and female (right) swimmers.

Silva et al., 2007

# Perl's Performance Potential Meta-model

Basis:

- Not a model per se, but a model of possible models

Advantages:

- Dynamically adapting
- Simulates real responses

Disadvantages:

- Has not been evaluated

# Perl's Performance Potential Meta-model

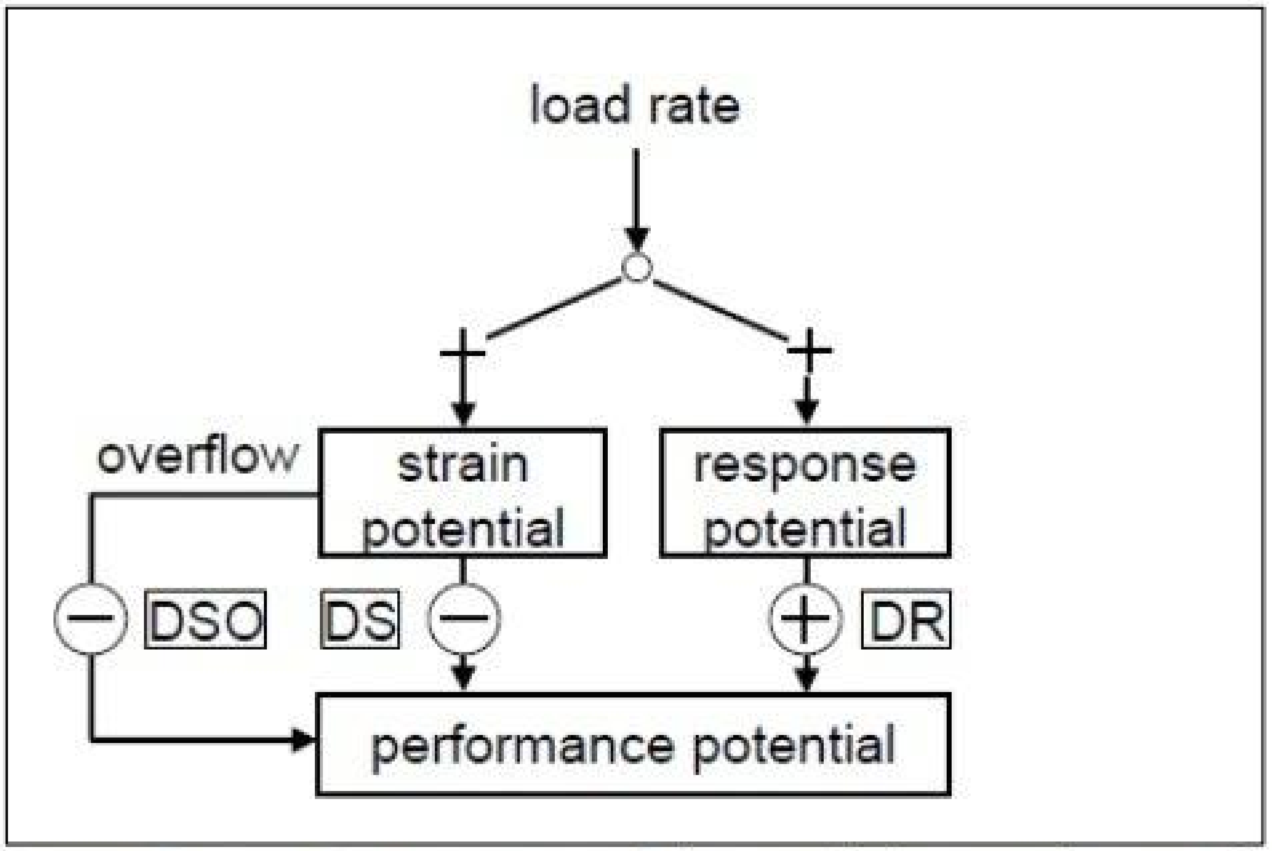



**Figure 3** : PERPOT meta-model containing strain overflow

Perl, 2000