# Theoretical View on Estimation of Postural and Induced Stressors Intensities in the Human Body by a Mathematical Dynamic Model

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***Abstract.*** *The work presents a theoretical view on applied system approach in orthostatic response by a linear transfer model of a dynamic system. From the viewpoint of parameters estimation theory, it regards to the nonlinear model of measurement. From the viewpoint of system theory, it regards to the identification of the system with incomplete information about the input function to the system and measured output function in discrete points. The results present the new potential markers for clarification of orthostatic dysregulation diagnosis.*

*Keywords: Stressor, Nonlinear Model of Measurement, Orthostatic Test, Physiological Circulatory Factor*

## 1. Introduction

The work deals with the identification of indirect measurements of the dynamic object investigation - human body, in the medical field, and mathematical formulation of responses by defining the system model of orthostatic test [1] from a theoretical point of view. The study is aimed to replace of non-computerized processing of the problem of change physiological circulatory factor (PCF), such as systolic pressure, diastolic pressure and hearth rate, based on postural change and represented stressors, with a model in the form of a linear transfer function of a dynamic system. A contribution to clarification of orthostatic dysregulation diagnosis [2-3] through the estimated parameters as potential new markers within the orthostatic criteria [4] is expected.

## 2. Subject and Methods

The identification of measurement orthostatic test, the pictogram of Fig. 2, is based on the methodological approach used in the Human Endocrinology Laboratory, the Institute of Experimental Endocrinology the Slovak Academy of Sciences in Bratislava [5-8]. The relationship of the cause and the consequence between stressors and the measured profiles of PCF explains the settlement of the orthostatic response to orthostatic test. The starting points to formation of a model system and to understanding the physiological function of the regulatory mechanisms of the real object present the question of quantification stimulus of stressors and distinguishing of dynamic and static properties of linear dynamic models on the tested system *en bloc*, respectively.

From the viewpoint of system approach in Fig. 1, the postural change, such as quick tilting bed with the subject shown in pictogram of Fig. 2, means the step input function $I(t)$ describing the stressors intensities-time profile connected in serial during the course *en bloc* of orthostatic test, where the individual values of intensity $I_i$ of stressors are not known [1]. The output function $V(t)$ presents the step response of measured value PCF, as a result of stressors exposure with unknown values of intensities $I_i$. In the reaction are known the time intervals $[t_{i-1}, t_i),\ i = 1,...,n$ of postural changes, where $n$ is the number of postural changes, exactly.

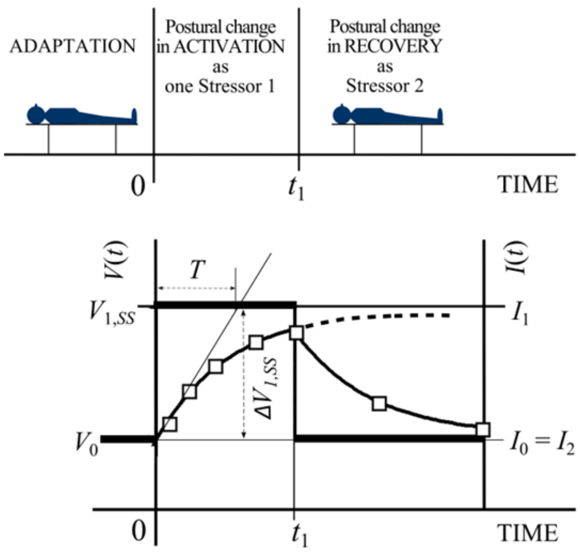


Fig. 1. System approach of General Orthostatic Test. $I(t)$ - input function of system, $V(t)$ - output function of system, $t$ - time, $V_0$ - basal value of measured PCF in the time of 0 min, $V_{1,SS}$ - value of PCF in hypothetic steady state, $\Delta V_{1,SS}$ - increase of PCF in hypothetic steady state, $\Delta V(t) = V(t) - V_0$, $\Delta V_{SS} = \Delta V(t)$ in time $t \to \infty$, $T$ - time constant, squares - measured PCF values, full line – simulation of model input function $I(t)$, $I$ - intensity of stressor, $I_i = \Delta V_{i,SS}$, kde $i = 1,2; \Rightarrow\ I_1 = \Delta V_{1,SS}, I_2 = \Delta V_{2,SS}$ .

The system defined by input-output functions is considered as linear, time-invariant, continual, dynamic system with incomplete information about the input function $I(t)$ [9].

Regarding the superposition property of the linear dynamic system, the time profile of output function $V(t)$ of measured values PCF, can be described as

$$V(t) = V_0 + \Delta V(t) \tag{1}$$

where $V(t)$ measured profile-values of PCF as output function of the system
$V_0$ basal value of measured PCF in the time of $t = 0$ min
$\Delta V(t)$ increase of PCF value induced by the orthostatic test.

The linear system with input $I(t)$ and output $V(t)$ characterizes the transfer function of the system as

$$H(s) = \frac{G}{1+Ts} = \frac{\Delta V(s)}{I(s)} \tag{2}$$

where $H(s)$ transfer function of the system
$G$ gain of the system
$\Delta V(s)$ Laplace transform of the system output
$s$ complex variable
$T$ time constant

The Laplace transform of the system input $I(s)$ is expressed as

$$I(s) = I_0 + \sum_{i=1}^{n+m} (I_{i-1} - I_i)\, e^{t_i - 1 - t} \tag{3}$$

where $I_i$ is the intensity of stressors under the zero initial conditions, $t_0$=0, $I_0$=$V_0$ as constant values.

The identification presents the determination of transfer function (2). For the description of system with the incomplete information, it is necessary to use the probability theory. Then the intensity value $I$ of stressor can be interpreted as the increase $\Delta V_{SS}$ of measured value of PCF in steady state; and static properties to estimate as a constant intensity $I_i$ of input function $I(t)$ at appropriate intervals of exposure of the stressor [1].

Instead of the gain parameter $G$, the static properties indicate parameter $I_i$ and dynamic properties indicate the parameter $T$.

## 3. Results

According to Fig. 2, one postural change may represent at least one stressor; and in the process of homeostasis is realized continually through physiological mechanisms in studied human body, though in the evaluation of orthostatic test is still not used.

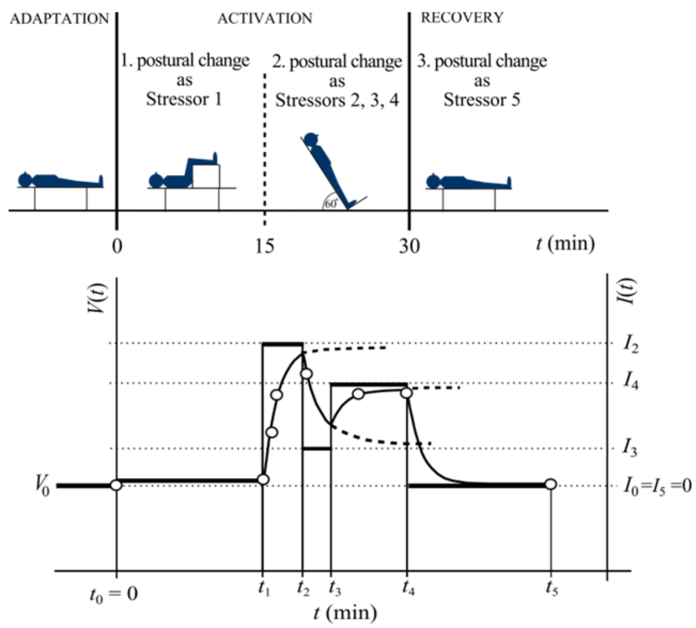


Fig. 2. The model of orthostatic test, where one postural change (2. postural change) represents three stressors, one hypothetical stressor and two induced stressors. $I(t)$ - input function of system, $V(t)$ - output function of system, circles - measured PCF values [1].

Figure 2 describes that second postural change in the activation phase of orthostatic test represents Stressor 2 and two induced Stressors 3 a 4.

The vector of estimated parameters λ of the nonlinear deterministic model has the form as

$$\lambda = (T, I_i; i = 1, 2, ..., (n+m); t_{x_j}, j = 0, 1, ..., m) \qquad (4)$$

where

| | |
|---|---|
| $T$ | time constant |
| $I_i$ | intensity of stressors, $I_i = \Delta V_{i,SS}$ |
| $x_j$ | induced stressors |
| $m$ | number of induced stressors |
| $n$ | number of postural change |
| $t_{xj}$ | starting-time exposure of induced stressors. |

Presented idea was confirmed in processing of measured profiles of PCF by the CTDB software package [9] in the work [1].

## 4. Discussion

Exposure to stressors, such as the postural changes, body temperature, hormones and chemicals, of the dynamic system - human body, is non-trivial to identify and quantify [6]. This work points to the theoretical severity and extensiveness of this problem together with previous publication [1] can represent the simple initial approach. It is a complex problem with time-consuming solving of the functional/dysfunctional regulatory mechanisms, in order to identify the possible causes. Therefore, the connection of the scientific disciplines is clearly required. The study of orthostatic response indicates a worldwide problem, where its final objectives, conclusions and proposed solutions depend on the complexity evaluable in time sequence. The development of mathematical models of observed system and distinguishing of dynamic and static properties, as the potential of new markers of linear dynamic models on tested system, can present the important contribution for better specification of diagnosis associated with orthostatic dysregulation [2,3].

## Acknowledgements

This work was supported by Scientific Grant Agency VEGA (Bratislava), grant No. 1/0120/12 and No. 2/0084/12, and Competence Center for SMART Technologies for Electronics and Informatics Systems and Services, ITMS 26240220072, funded by the Research & Development Operational Program from the ERDF.

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