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Effect of flue on stationary states and processes in the cardio-pulmonary system described in Quantum Biological Thermodynamics with Finite Speed

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Abstract. The paper presents the symptomatology on a 72-hours period, of a person (77 years old) who is ill with flu, based on the 5 Diagrams invented within the Quantum Biological Thermodynamics of the Cardio-Pulmonary System. These diagrams, in which Stationary States and Processes between them are represented, with or without Quantum Jump, illustrate variations of Heart (F_H) and Lungs (F_L) Frequencies, of the rate $R_f = F_H / F_L$, of the percentage of oxygen in the blood and of the Quantum Number N corresponding to each Stationary State. The analysis of the 5 diagrams provides interesting conclusions that reveal the serious consequences of this disease on the Cardio-Pulmonary System of the person concerned, in comparison with his normal health condition.

1. Introduction

In the last 5 years it was developed a new branch of *Irreversible Thermodynamics* called: *Quantum Biological Thermodynamics with Finite Speed of the Cardio-Pulmonary System.* (QBTFSCPS), [1-10], based on the achievements in *Thermodynamics with Finite Speed* (TFS) [11-13].

The modeling of the *Cardio-Pulmonary System* became possible after the extension of TFS to the study and optimization of Fuel Cells [14] started in 1993, based on previous researches related to Fuel Cells [15-19] and after the Validation of TFS for 15 Stirling Engines (the most performant in the World: USA, German, Japan, New Zeeland) after 2002 [20-28].

The extension of the Thermodynamics with Finite Speed to Biological Systems has as an essential objective the study of the cardio-pulmonary system, which plays an extremely important and vital role in the functioning of any being with blood (including humans). For stationary states, *the fundamental status parameters* introduced are: *heart rate*, F_H, *lung frequency*, F_L and their ratio, R_f, to describe the self-organized interaction between them.

With these new state parameters, processes between stationary states can also be described. The Frequencies of Heart and Lungs are proportional to the power consumed by the Heart and the Lungs respectively. Therefore, the R_f ratio will be proportional to the ratio of them and will characterize the interaction of the two subsystems (Heart and Lungs).

The experiments were conducted to study the interaction processes within the human cardiovascular system as a result of position changes, performing actions such as eating, walking,

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climbing or descending stairs, etc. with the support of over 180 people led to this extremely important parameter, R_f, which is a function of a *"quantum number", N (integer)*.

Also essential for the extension of Irreversible Thermodynamics to Quantum Biological Thermodynamics with Finite Speed were the new *pV/px diagram* for Heart and Lungs functioning [1], the new specific processes in the Cardio-Pulmonary System, the equations describing them and the five diagrams for study of *the stationary states and of the processes with and without Quantum Jump*.

In this paper we present the symptomatology over a 72-hours' time period, of a person (77 years old) who is ill with flu, based on the *5 Diagrams invented* within Quantum Biological Thermodynamics with Finite Speed for the Cardio-Pulmonary System (QBTFSCPS). These diagrams reveal the *significant consequences* on the functioning of the *Cardio-Pulmonary System* of the person concerned, in comparison with his normal health condition.

2. Fundamentals of Quantum Biological Thermodynamics with Finite Speed for the Cardio-Pulmonary System

Based on experiments analysis we have done on thousands measurements of Heart (F_H) and Lung (F_L) *Frequencies* in *Stationary States* on different persons and after plotting the diagram F_H = f(F_L) [3], it was discovered *a very simple equation* correlating these two *oscillation frequencies:*

$$F_H = F_L\left(2+\frac{N}{4}\right) \tag{1}$$

where *N* is an integer number that we called *quantum number of the interaction between the Heart and Lungs in any stationary state,* in any healthy person.

It resulted that if a person does not achieve easy and quite fast (1-2 minutes) such a state, equation (1) is not validated for she or he, which means this person may have already illness or will have it in the future. The explanation of equation (1) is based on the Synergetic-Interaction between the two oscillators (Heart and Lung) which tend to be organized in an *optimum functioning*. After the invention of Advanced Synergetics by Herman Hacken [29], and this subject was resumed by Adelina Georgescu [30], more and more researchers (for example Y. Kuramoto, [31]) studied and agreed that *the interaction between two oscillators* (of any origin: mechanical, electrical, chemical, biological etc.) *have the tendency to self-organize* in such a way that *a superior degree of order is obtained by itself in that system*. The discovery and the development of QBTFS was achieved in a similar way in the case of the *Cardio- Pulmonary System*. This *superior degree of order* is expresses by formula (1). People who are healthy tend to respect this formula which means they have a high degree of order in them, but the people who do not (anymore) respect this formula have a tendency to get ill or have already an illness, which introduces a degree of disorder in the interaction between Heart and Lungs.

As a consequence of this Self-organization, for healthy people, the two previously mentioned frequencies **(**F_H or/and F_L) may be constant (for minutes, tens of minutes or even hours) in what its called S*tationary Quantum States* (SQS), when laying, sitting on a chair, walking, or doing repetitive physical work etc. In addition to that, after a certain action the Stationary State is changed, also in an organized way, in agreement with the equations presented in the section 3.

3. Equations of Processes with or without Quantum Jump in Cardio-Pulmonary System

If the points corresponding to two *successive Stationary States* are connected it results a *process line* similar with the lines illustrating Reversible Processes in Classical Thermodynamics (CT) diagrams, such as p-V, T-S, h-s etc., generally used in Thermal Machines study and design.

Applied to the *successive Quantum Stationary States* 1 and 2, representing the initial and final states of a process, equation (1) can be written as:

$$F_{H,1} = F_{L,1}\left(2+\frac{N_1}{4}\right) \tag{2}$$

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$$F_{H,2} = F_{L,2}\left(2 + \frac{N_2}{4}\right). \tag{3}$$

As in CT, three equations of the human Cardio-Pulmonary System will result from equations (2) and (3), when a *state parameter* is kept constant during each corresponding process (representing the passage from one stationary state to another). Thus it may have:

- Iso-Pulse process equation when F_H = *constant*:

$$\frac{F_{L,2}}{F_{L,1}} = \frac{8+N_1}{8+N_2} \tag{4}$$

- Iso-Rhythm process equation when F_L = *constant*:

$$\frac{F_{H,2}}{F_{H,1}} = \frac{8+N_2}{8+N_1} \tag{5}$$

- Iso-Quantum process equation when N = *constant*:

$$\frac{F_{H,2}}{F_{H,1}} = \frac{F_{L,2}}{F_{L,1}}. \tag{6}$$

The general process corresponding to the polytropic one in Classical Thermodynamics is introduced by the *polytropic factor* given by the slope of the process line:

$$\mu = \frac{\Delta N}{\Delta F_L}. \tag{7}$$

By discovering with experimental measurements of F_H and F_L the connection between the *slope of polytropic process* and *change of position* (from horizontal to vertical position, or from sitting on a chair to standing position, for example) or other *processes generated by activities* (eating, walking, running, climbing up on stairs or on hill) one can express the polytropic equation as:

$$F_{H,2} = F_{L,2}\cdot\left(2 + \frac{N_1}{4} + \mu\frac{F_{L,2} - F_{L,1}}{4}\right). \tag{8}$$

Note that equation (8) provides the expression of the Heart frequency in the final Quantum Stationary State 2 that will enter in the computation of the Power needed by the Cardio-Pulmonary System. Hence, the power of the Heart results *as function only of* F_L, similarly to the computations of the cycles in Thermal Machines.

4. How Flu affects the Heart-Lung Interaction and Processes

The SP (77 years) person conducted measurements of the F_H and F_L frequencies in different positions over 4 days while having flu.

In order to emphasize the effect of the flu on the Cardio-Pulmonary System operation, experimental measurements taken before (healthy state) and during the flu are presented in table 1 and table 2. One can see that if the frequency of the lungs increases by about 22%, the heart frequency almost doubles at the beginning of the first day of the flu (comparison of states 0 to 1 in the two tables). This discrepancy is progressively reduced over the next 2 days (states 7' to 19', then states 20" to 38" in table 2), due to medication, so that normal values are reached on the fourth day (state 39 and 39*). The increase in hearth frequency at the onset of flu affects upward the ratio R_f and the quantum number N. The only functional parameter that presents comparable values is the content of oxygen. A

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plausible explanation would be that the increased activity of the hearth provides good oxygenation of the cells, thus helping to fight against the flu effect.

Table 1. Measured frequency values of the heart, F_H, and the lungs, F_L for healthy state condition, and corresponding computed data (R_f, N, O_2).

State	Lung frequency (osc min^{-1})	Heart frequency (osc min^{-1})	Frequency ratio (-)	Quantum number (-)	Oxygen content (%)
0	22	66	3	4	98
1	21	63	3	4	98
2	21	84	4	8	98
3	21	84	4	8	99
4	21	84	4	8	98
5	21	79	3.76	7	98
6	25	100	4	8	97
7	24	93	3.87	7	98
8	20.5	82	4	8	98
9	20	80	4	8	98
10	20	80	4	8	98
11	22	91	4.13	9	98
12	22.5	95	4.22	9	98
13	21	79	3.76	7	97
14	22	77	3.5	6	97
15	20	75	3.75	7	97
16	20	75	3.75	7	98
17	22	82	3.73	7	99
18	22	66	3	4	98
19	23	92	4	8	97
20	24	90	3.75	7	98
21	20	77	3.85	7	97
22	20	77	3.85	7	99
23	22	72	3.27	5	98
24	20	77	3.85	7	97
25	18	75	4.18	9	97
26	21	75	3.57	6	98
27	21	73	3.58	6	97
28	22	77	3.5	6	98
29	20	70	3.5	6	98
30	21	71	3.33	5	98
31	19	71	3.74	7	98
32	20	70	3.5	6	97
33	23	69	3	4	97
34	20	60	3	4	97
35	20	60	3	4	98
36	20	60	3	4	98
37	24	61	2.54	2	98
38	24.5	61	2.49	2	98
39	22	66	3	4	98

Table 2. Measured frequency values of the heart, F_H, and the lungs, F_L under the effects of flue, and corresponding computed data (R_f, N, O_2).

State	Lung frequency (osc min^{-1})	Heart frequency (osc min^{-1})	Frequency ratio (-)	Quantum number (-)	Oxygen content (%)
0	27	121	4.48	10	98
1	27	108	4	8	98
2	27	115	4.25	9	98
3	28	111	3.96	8	96
4	28	112	4	8	96
5	27	108	4	8	97
6	26	103	3.96	8	98
7'	25	88	3.52	6	98
8'	25	88	3.52	6	98
9'	23	98	4.26	9	97
10'	24	102	4.25	9	98
11'	25	82	3.28	5	98
12'	22	77	3.5	6	98
13'	28	78	2.78	3	97
14'	27	85	3.15	5	97
15'	27	84	3.11	4	96
16'	27	82	3.04	4	96
17'	26	79	3.03	4	96
18'	27	82	3.03	4	97
19'	22	66	3	4	97
20"	22	66	3	4	98
21"	23	75	3.26	5	97
22"	23	89	3.86	7	98
23"	22	90	4.09	8	98
24"	23	69	3	4	98
25"	22	82	3.72	7	98
26"	22	77	3.5	6	98
27"	25	93	3.72	7	98
28"	26	67	2.57	2	99
29"	23	68	2.96	4	98
30"	23	69	3	4	98
31"	23	85	3.69	7	98
32"	23	71	3.08	4	98
33"	21.5	70	3.25	5	98
34"	25	82	3.28	5	98
35"	24	75	3.125	5	97
36"	24	72	3	4	98
37"	22	78	3.54	6	98
38"	22	66	3	4	98
39*	23	64	2.78	3	98

Based on the measurements of the lung and heart frequencies during the flu, the 5 diagrams in the QBTFS previously mentioned were plotted (figure 1 to figure 6). The figures present different dependencies of the measured parameters in stationary states corresponding to different positions (standing, sitting on a chair, lying in bed) and the processes between them that occur when changing the position. Thus, figure 1 illustrates the diagram of the heart frequency versus the lung frequency,

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while figure 2 brings together the variation of two parameters, namely, the frequency ratio R_f and the quantum N, versus the lung frequency. The third diagram (figure 3) gives priority to the lung frequency, represented as a function of heart frequency, while the fourth diagram (figure 4) is similar with the second one, but changes the abscissa to heart frequency. The fifth diagram is composed by two parts, showing the experimental results (figure 5) and the calculated one (figure 6) for each considered state.

Looking to all these figures, we observe a very “strong and negative” effect of the flu on the person with this condition.

After taking some medicine the situation is improved step by step and the main parameters of the Cardio Pulmonary System F_H and F_L drop down to normal values.

The successive states 0-6 (delimited with a red dotted line) are in the domain of very high values of F_H and F_L, situation in which the person does not fill well and have fever.

On the second day, the SP started to feel better, which also results from the analysis of diagrams in which states 7'-19 '(delimited with a blue dotted line) correspond to lower values of the two fundamental status parameters.

On the 3rd day, the states 20"-38" in the diagrams (bounded by green interrupted line) the person SP's health status improved considerably and on 4th day (the state 39*) the person returned to normal physiological parameters.

The analysis of fundamental status parameters, F_H, F_L, R_f and N, reveals very interesting situations. Respectively, while SP was ill with flu, the F_H and F_L parameters had high values as in the situations where he would have made a great effort to carry out some activities.

Hence, the conclusion is that while a person is ill with flu, it is necessary to pay more attention to rest and avoid activities that involve great physical and mental effort, to not overload the body.

It is also noted that, though during the time the person was ill with the flu, the F_H and F_L frequencies have reached high values, the size of the R_f ratio that characterizes the Heart-Lung interaction remained about the same as if the person was healthy.

Therefore, this is an indication that the flu has not significantly negatively influenced the optimal interaction between the Heart and Lungs.

The processes determined by the equations (4)-(6) are illustrated in the 5 diagrams constructed on the basis of the measured values of the frequencies F_H and F_L status parameters, the percentage of oxygen in the blood tissue and of the calculated ones (R_f, N and μ) presented in Table 2.

The measurements made by the SP person were based on an established protocol, by recording the F_H and F_L frequencies between the stationary states and studying the various *elementary processes* (changing the position from bed to chair, standing chair and vice versa, serving table: small lunch, lunch, dinner, excretion process, sleep).

The percentage of O_2 in the blood was also measured. As is already known in Anatomy and Physiology [32,33], it plays a vital role in the Heart with Lungs interact. Namely pulmonary frequency control F_L is performed by the Heart, by the Oxygen concentration, O_2 [%], in the blood, with the Cybernetic System called *Baroreflex System*.

Figure 5 and figure 6 illustrate very interesting correlations between changes in blood O_2 percentage, heart frequency F_H, pulmonary frequency F_L, ratio of R_f and quantum number N as Cardio-Pulmonary System's state number functions (0, 1, 2, 3 , 4, ..., 39) during elementary processes without physical effort, which were presented in the 40 states.

If the percentage of O_2 drops below 95%, according to anatomical and physiological studies [32,33], the blood does not contain enough Oxygen. In this case, the person may now or in the future have an important health problem. In most states the O_2 percentage was 97%, and in one of the states it reached the maximum value (99%). At the same time, it points out that the lowest level of O_2 was recorded when the flu was at the maximum.

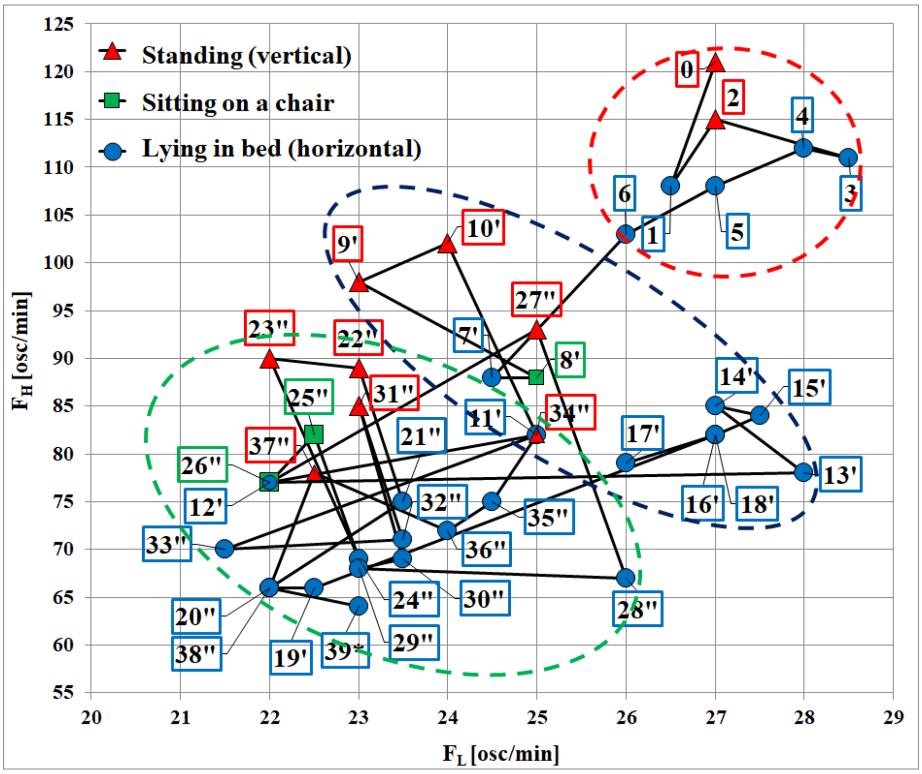

Figure 1. Stationary states and processes represented in F_H = f(F_L) diagram.

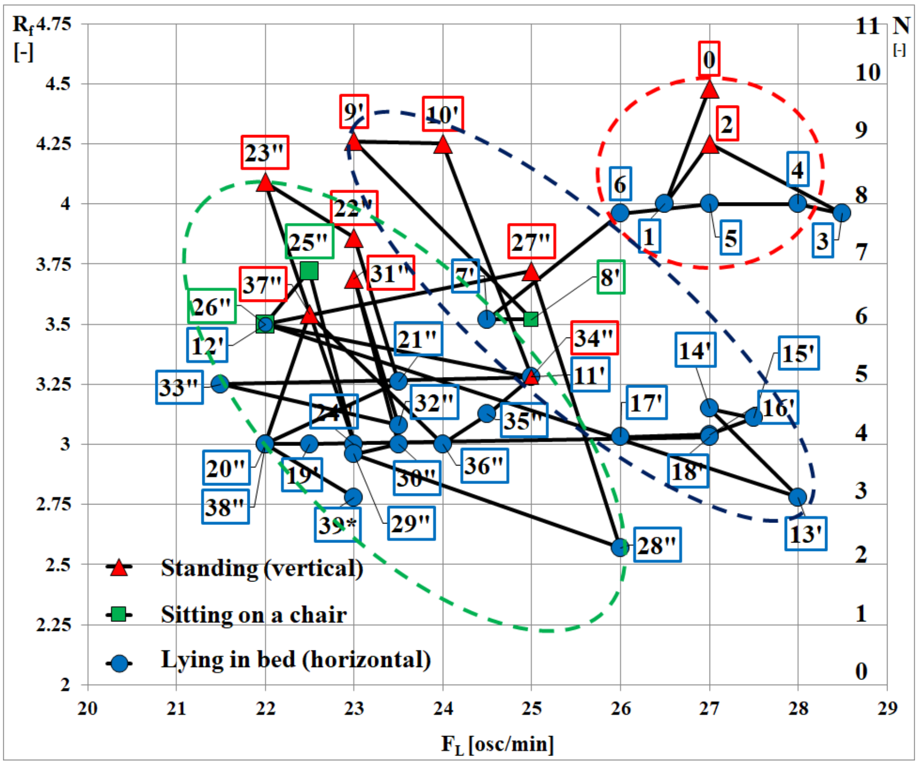

Figure 2. Frequency ratio, R_f, and quantum number, N dependence on the lung frequency, F_L.

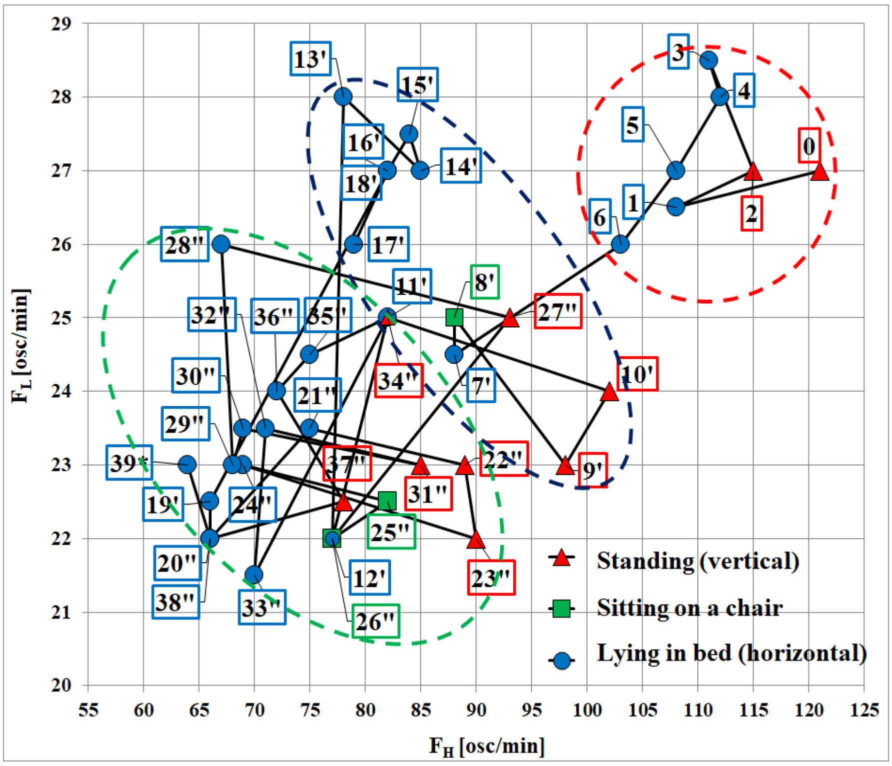

Figure 3. Stationary states and processes represented in F_L = f(F_H) diagram.

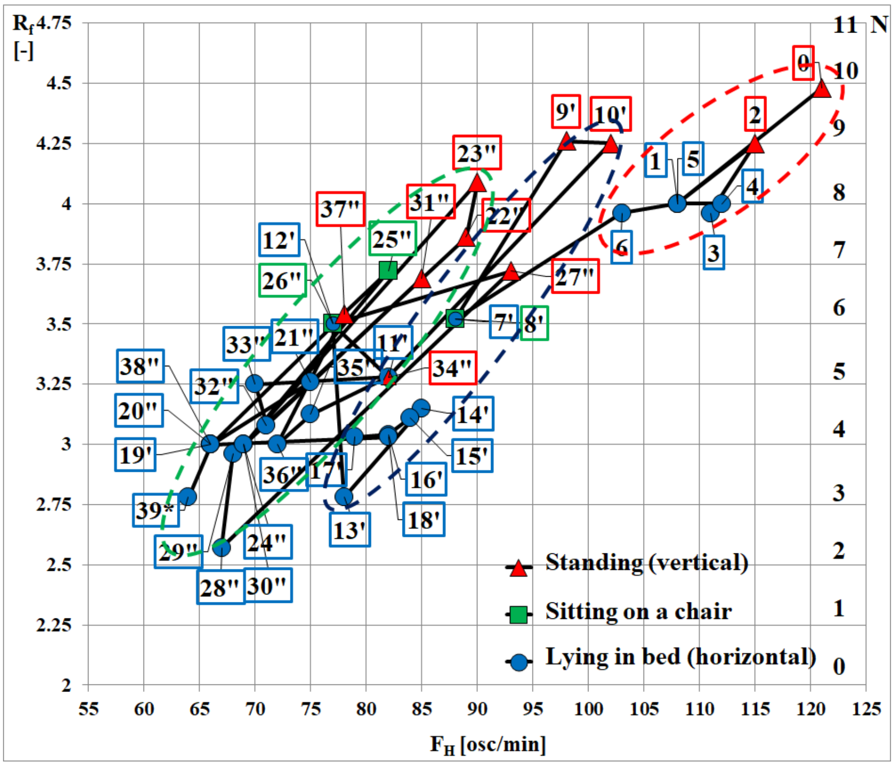

Figure 4. Frequency ratio, R_f, and quantum number, N dependence on the heart frequency, F_H.

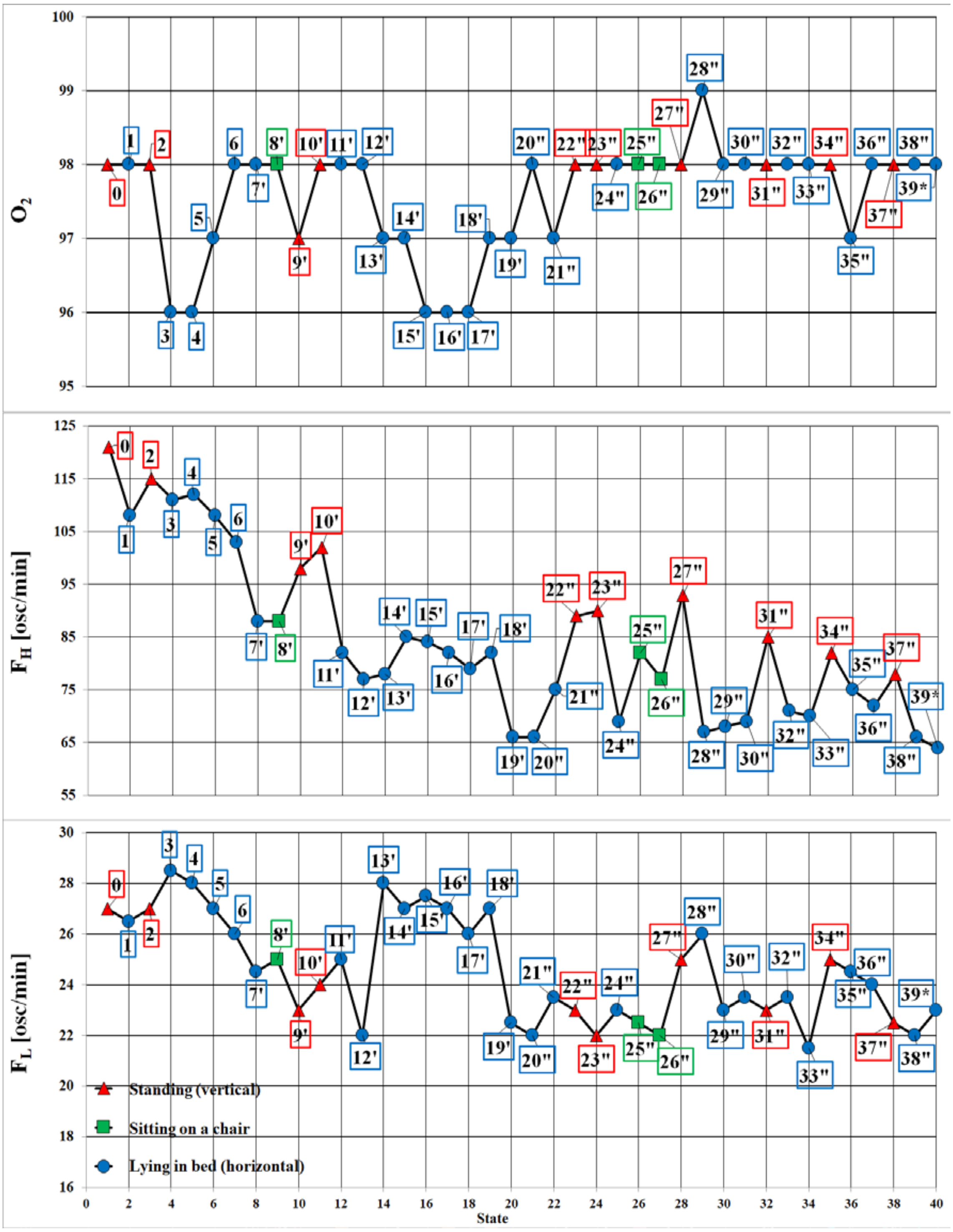

Figure 5. Diagram illustrating the dependences: $O_2 = f$(state number); $F_H = f$(state number); $F_L = f\ f$(state number).

The analysis of figure 5, namely the two dependencies: $F_H = f$(state number) and $F_L = f$(state number), shows the tendency of decreasing the Heart and Lung frequencies, which results in a good correlation between the two "machines", the blood pump - the Heart and the air compressor - the whole of the two Lungs together with the return to a good state of health.

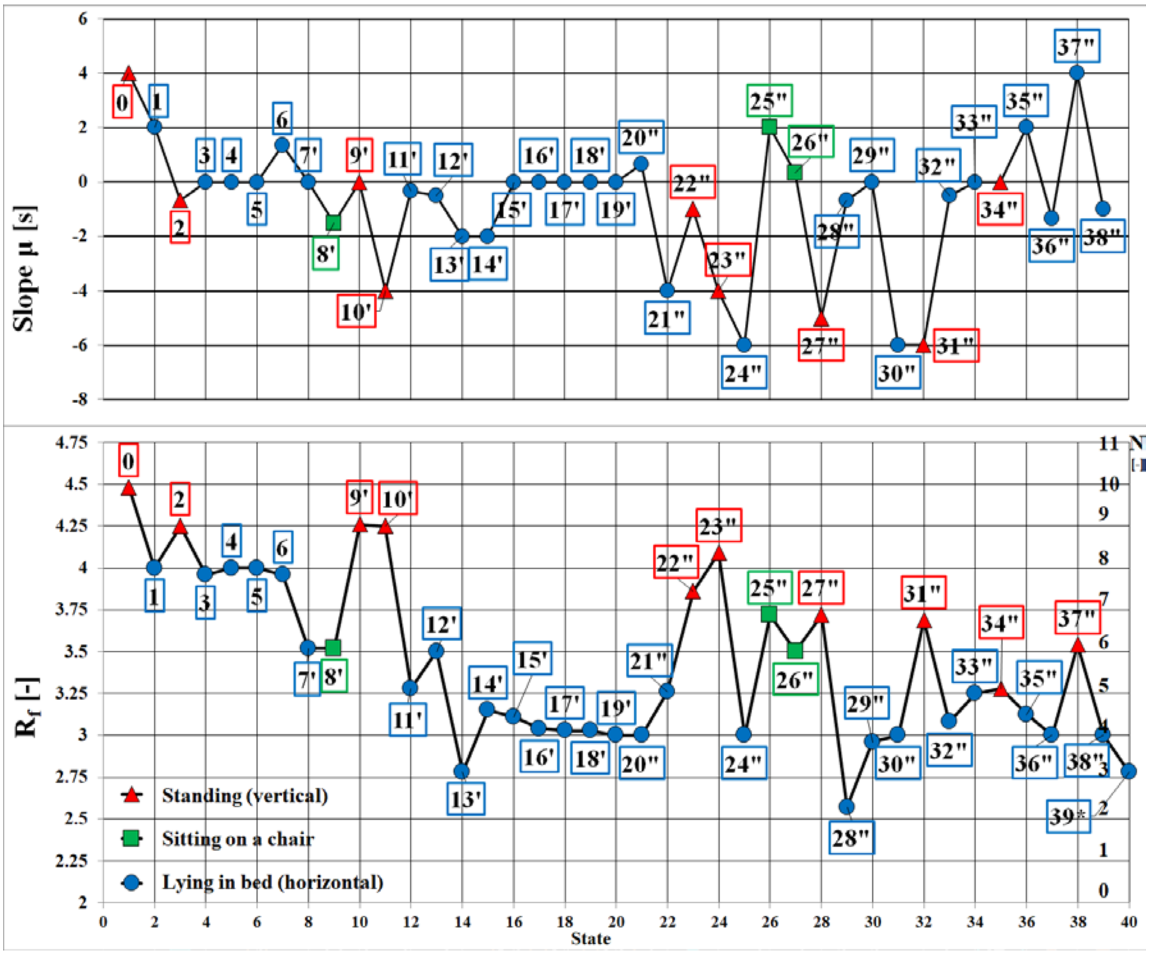

Figure 6. Diagram illustrating $\mu = f$(state number) and R_f, $N = f$(state number).

Many process lines from the diagrams illustrated in the above figures are parallel. Those processes having all the same slope ($\Delta F_L/\Delta F_H$, $\Delta N/\Delta F_H$, $\Delta F_H/\Delta F_L$, $\Delta N/\Delta F_L$) may be characterized as "iso-slope" processes:

- Iso-Rhythm (F_L = constant): 0-1; 1-2, 3-4; 14'-15'; 15'-16'; 21"-22"; 25"-26"; 29"-30";30"-31"; 35"-36"; 37"-38"
- Iso-Quantum Number (N = constant): 4-5; 9'-10'; 16'-17'; 17'-18'; 18'-19'; 19"-20"; 33"-34"
- Iso-Pulse with F_H constant: 12'-13'
- Iso-Slope, polytrophic process (μ = constant): μ_{2-3}, $\mu_{22''-23''}$, $\mu_{36''-37''}$, $\mu_{38''-39''}$ for μ= -1, and μ_{4-5}, μ_{5-6}, $\mu_{9'-10'}$, $\mu_{16'-17'}$, $\mu_{17'-18'}$, $\mu_{18'-19'}$, $\mu_{33''-34''}$, $\mu_{34''-35''}$ for μ= 0.

Their same slope shows in fact that for these processes the ratio between the variation of the corresponding stationary state parameters is the same.

The results presented in figure 6 are representative for the processes between stationary states, showing the slope variation for the polytropic processes and the corresponding quantum jump.

5. Conclusions and Perspectives

The 5 diagrams invented in QBTFS and presented above can be drawn either in the normal health situation or in the illness one. They provide very important information regarding the functioning of the Cardio-Pulmonary System.

This information could be very useful in the case that such a person need either a Pacemaker or even an Artificial Heart.

The two devices can now be designed on a personalized bases using such diagrams obtained by any person before it needs artificial devices in order to save its life. For example, a Pacemaker could be adjusted so that it corresponds to the domain of Heart and Lungs Frequencies and the correlations between them through R_f and the Quantum Number.

In a previous paper we have presented these diagrams for many persons showing how different we are from the point of view of Heart-Lungs Interaction, which is a very strong indication that personalized pacemakers and personalized artificial hearts must be designed in the future, based on such Personalized Diagrams, obtained by each person before getting ill.

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