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Doppler Effect: A Look from Biology Aging

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Abstract

The Doppler effect can be defined as the frequency shift suffered by a wave phenomenon, when there is a difference in relative speed between the waves generated and their source. We know that it occurs in the case of mechanical and electromagnetic waves. We propose to generalize the Doppler effect to the case of frequency changes of certain oscillatory variables in biology before and after puberty, starting from the basis that a metabolically accelerated system is equivalent to a mechanically accelerated system. We then established the following objectives: To verify if there is an average difference in heart and respiratory rates, before and after puberty. To verify the association of these frequency differences with the metabolic activity estimated as basal metabolic rate or BMR. We studied heart and respiratory rate data from healthy people of both sexes, verifying the frequency distribution before and after puberty. We also study the relationship of the frequency distribution with the evolution of the basal metabolic rate throughout life. Analysis of the results shows that the highest heart and respiratory rates occur before puberty, while the lowest rates occur after puberty. A high correlation of the evolution of the variables studied with the evolution of the metabolic acceleration of the system throughout life is also evident. Taking into account that a mechanically accelerated system is equivalent to a metabolically accelerated system, we can conclude that the frequency distribution found is the expression of a generalization of the Doppler effect in the case of biological physical systems.

Keywords

Oscillatory Variables, Metabolic Acceleration, Mechanical Acceleration, Equivalence Principle, Non-Inertial System, Rate of Change

1. Introduction

In previous studies, we have analyzed the description of living beings as oscillatory systems, like a package of waves. This includes the description of human aging and living beings in general [1] [2].

It is essential to consider living beings as physical systems that dissipate energy and recover it as information (generate their own structure) [3]-[5].

Thus, the self-organized systems present various oscillatory variables that, although asynchronous with each other, are in conflict during the growth of the living being.

The tendency of these systems to order depends on their own geometry: they tend to order and therefore to keep their variables in a phase when their curvature is null, neutral, or positive and of equal value at all its points [6]-[8]. This tendency to order is maintained as long as the system continues to recover more and more information in an increasingly larger space (because it is growing) [9] [10].

The case of human aging is a notable example. Shortly after puberty, growth ends and then the information density increases, because more and more information is recovered in a space that is no longer growing. The geometry of the system changes. A geometric phase shift occurs, which is seen as aging: as the Chrono disruption of the oscillatory variables of the system, because cycle after cycle these variables no longer recover their original values [11]-[13]. That is the reason why the homeostasis of the system gradually declines [14] [15].

But it is one thing to specify that the system changes (and know the cause of its change) and another to describe how changes occur in the system. The description of how the oscillatory variables change at the end of growth implies knowing their oscillatory frequencies before and after puberty. It is important to know if there is a general tendency to increase or decrease the oscillatory frequencies, or if the mentioned changes do not present any trend [16] [17].

Why is this important? Because we know that for any wave system, if there is a difference in relative speed between the source and the waves it produces, a shift in the frequency of the waves will occur, known as the Doppler effect [18] [19]. This phenomenon is seen both in the case of mechanical and electromagnetic waves [20] [21].

The source of the waves is the metabolic activity of the living being and since complex living beings behave in a manner equivalent to what in mechanics is an accelerated (non-inertial) system [9], the situation generates the conditions for the Doppler effect to occur: waves always have the same speed in a given medium and if their source is accelerated (even if it is a negative acceleration, in any case, the source does not always have the same speed), at some point, there will be a difference in relative speed between the waves and their source (we will not extend the analysis of the role of the observer in the situation at hand).

To simplify the present study, we will verify the behavior of two oscillatory variables such as heart rate and respiratory rate. It is not necessary to study the behavior of all oscillatory variables, since the source is the same for all of them and is accelerated.

Our objectives are:

-To verify if there is an average difference in heart and respiratory rates, before and after puberty.

-To verify the association of these frequency differences with the metabolic activity estimated as basal metabolic rate or BMR.

2. Materials and Methods

Data processing complies with the Declaration of Helsinki and respects the conditions of the ethics committee (EX-2021-85190521) of its source (National Center for Care of Elderly, Argentine).

The study included data from people of both sexes who were clinically healthy at time of study. However, data from people with particular pathologies or physiological conditions such as pregnancy or overweight were excluded.

The average heart rate was studied in healthy human beings of both sexes at rest and the values obtained before and after puberty were compared.

Similarly, we compared the average respiratory rate in healthy human beings of both sexes at rest, before and after puberty (see Table 1).

An analysis of the difference in means before and after puberty of these variables allows us to determine if these differences are statistically significant. For this reason, comparisons were evaluated by applying Student's t-test (see Table 2).

The evolution of BMR per unit of body mass was also studied in human beings of both sexes and its relationship with the evolution of heart rate and respiratory rate throughout life.

When we refer to the unit of body mass, we take the values of the unit of water-free body mass or dry weight (see Table 3). This assures us that we are considering metabolically active body mass as a reference [22].

Table 1. Shows the values of age and heart rate in humans beings of both sexes. Sample demographic characteristics: Argentine population (white race). Sample size: n = 5100.

Age (years)	Heart rate (BPM)
0 - 0.5	160
0.5 - 1	120
1 - 3	110
4 - 6	105
7 - 10	100
11 - 14	95
15 - 18	90
19 - 24	80
25 - 50	70
51 or more	60

Table 2. Shows the values of age and respiratory rate in humans beings of both sexes. Sample demographic characteristics: Argentine population (white race). Sample size: n = 5100.

Age (years)	Respiratory rate (BPM)
0 - 0.5	60
0.5 - 1	45
1 - 3	42
4 - 6	32
7 - 10	31
11 - 14	28
15 - 18	24
19 - 24	20
25 - 50	16
51 or more	14

Table 3. Shows the values of age, heart rates, respiratory rates and energy dissipation in humans beings of both sexes. Sample demographic characteristics: Argentine population (white race). Sample size: n = 5100.

Age (years)	Heart rate (BPM)	BMR/kg (Kcal/dry weight)	Respiratory rate (BPM)
0 - 0.5	160	228	60
0.5 - 1	120	172	45
1 - 3	110	160	42
4 - 6	105	125	32
7 - 10	100	103	31
11 - 14	95	80	28
15 - 18	90	63	24
19 - 24	80	57	20
25 - 50	70	51	16
51 or more	60	44	14

An R^2 correlation test (coefficient of determination) applied to the evolution of these variables (BMR/kg of dry weight, respiratory rate and heart rate), allows us to determine the degree of association between them.

3. Results

The distribution of heart rate before and after puberty is shown in **Figure 1**. To evaluate the difference in averages (before and after puberty), Student's t-test was applied, with a result of 19.5 ($p \leq 0.01$), which is statistically significant.

The distribution of respiratory frequency before and after puberty is shown in

Figure 2. To evaluate the difference in averages, student's t-test was also applied, with a statistically significant result of 2.1 ($p \leq 0.01$).

The relationship between BMR/kg dry weight and heart rate throughout life (before and after puberty) is shown in Figure 3. When evaluating the correlation between these variables, $R^2 = 0.92$ ($p \leq 0.02$) was obtained. This is statistically significant.

The relationship between BMR/kg dry weight and respiratory rate frequency throughout life (before and after puberty) is shown in Figure 4. When evaluating the correlation between these variables, $R^2 = 0.97$ ($p \leq 0.01$), it is statistically significant.

Analysis of the frequency distribution shows that the highest heart and respiratory rates occur before puberty, while the lowest frequencies occur after puberty. They also show a high correlation between the evolution of heart and respiratory rates with the evolution of BMR/kg of dry weight throughout life.

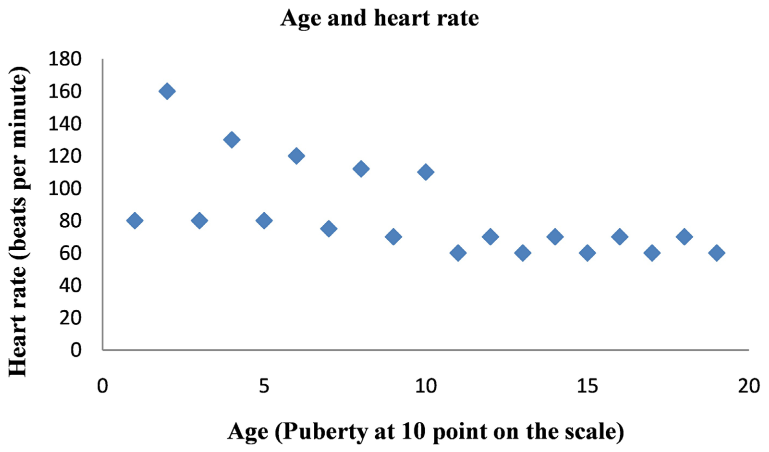

Figure 1. Heart rate variation throughout life. There is significant difference before and after puberty ($p \leq 0.01$). Sample demographic characteristics: Argentine population (white race). Sample size: n = 5100.

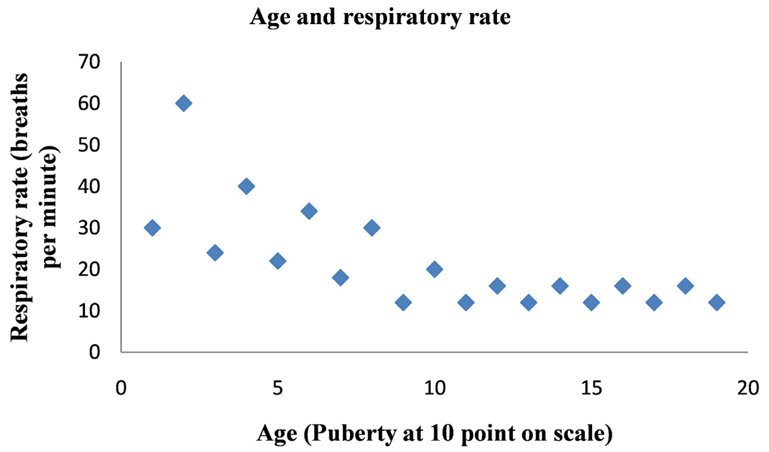

Figure 2. Respiratory rate variation throughout life. There is significant difference before and after puberty ($p \leq 0.01$). Sample demographic characteristics: Argentine population (white race). Sample size: n = 5100.

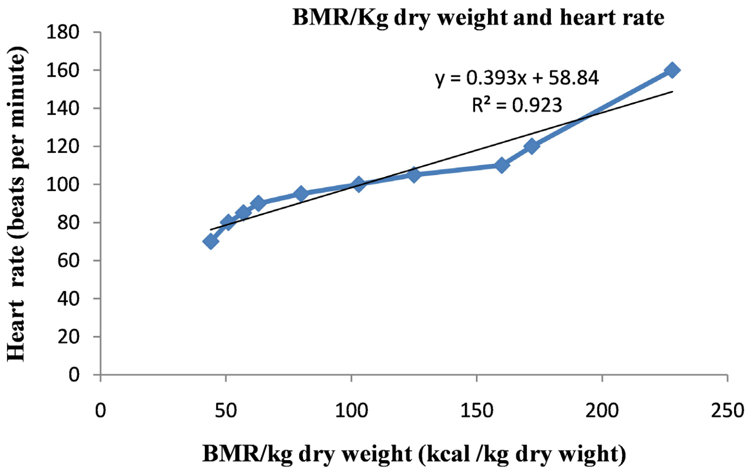

Figure 3. Correlation between BMR/kg dry weight and heart rate. There is significant correlation ($p \leq 0.02$). Sample demographic characteristics: Argentine population (white race). Sample size: n = 5100.

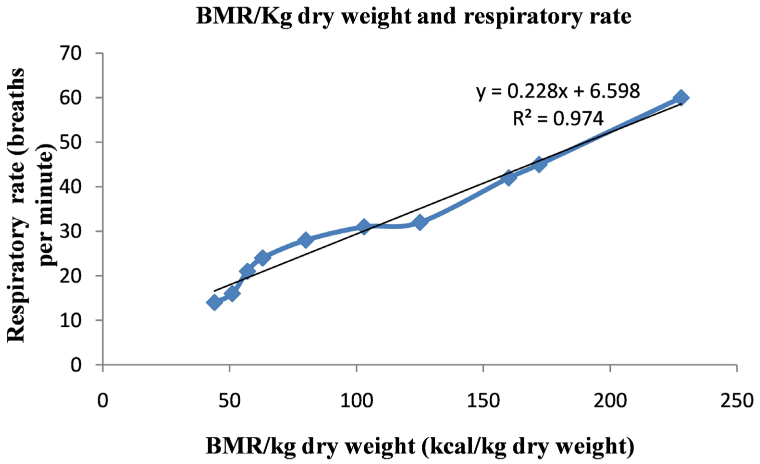

Figure 4. Correlation between BMR/kg dry weight and respiratory rate. There is significant correlation ($p \leq 0.01$). Sample demographic characteristics: Argentine population (white race). Sample size: n = 5100.

4. Discussion

The results obtained can only have meaning in the reference framework that we propose: The frequencies of the oscillatory variables studied are directly related to the metabolic acceleration that occurs in the system. Since the speed of a wave is always the same in a given medium, when its source is accelerated (metabolic acceleration), a difference in relative speed occurs between the waves and their source.

This allows us to understand the frequency distribution of oscillatory variables, higher before puberty and lower after puberty, as a generalization of the Doppler effect in biology.

We speak of a "generalization of the Doppler effect" and not of the "Doppler effect applied" to biology, because we understand that the meaning is not the same. The "Doppler effect applied" to biology is the case of the study of blood flow in arterial or venous vessels, or even in the heart. It is nothing more than a study of the frequency variations in mechanical waves, which are produced when blood flow is altered. It is nothing more than classical physics applied to biology [23]-[25].

But when we talk about "generalized Doppler effect", we are referring to the following: A multicellular living being is a complex physical system, made up of systems subsumed into systems. Then, it is equivalent to a non-inertial reference system of classical mechanics. In previous works, we called this condition "equivalence principle" [9] [26].

This is because a multicellular living being is a metabolically accelerated biological physical system, in the same way that in the case of mechanics a non-inertial system is an accelerated physical system (it could be a system that is rotating, or that changes its direction or its speed) [27] [28].

As the source of the oscillations is the accelerated metabolic activity of the system, and taking into account that the speed of the waves is constant in a given medium, then the frequency of the waves will be affected (Doppler effect). But this is no longer the simple application of mechanical waves to living beings. This involves recognizing that a metabolically accelerated system and a mechanically accelerated system are equivalent physical systems.

The frequency changes that we observed before and after puberty in the variables studied represent a generalization of the Doppler effect beyond mechanical and electromagnetic waves.

We formalize the metabolic acceleration as Ma = BMR/m^2, where Ma is the metabolic acceleration; *BMR* is the energy dissipated, expressed in kcal per unit of mass $\frac{kcal}{m}$ and m is the mass expressed in kg of weight.

So, the metabolic acceleration is $Ma = \frac{\frac{kcal}{m}}{m} = \frac{kcal}{m^2}$. We formalize the mechanical acceleration as $A = \frac{d}{t^2}$ where *A* is the mechanical acceleration*;* *d* is the distance traveled per unit of time, expressed in meters per second; and *t* is the time expressed in seconds.

As the speed is $v = \frac{d}{t}$, where *d* is the distance expressed in meters and *t* is the time expressed in seconds.

Therefore, the mechanical acceleration is $A = \frac{\frac{m}{s}}{s} = \frac{m}{s^2}$.

We define this logical equivalence as:

$$\frac{BMR}{m^2} :\Leftrightarrow \frac{d}{t^2}$$

Or in terms of its units as:

$$\frac{kcal}{m2} :\Leftrightarrow \frac{m}{s^2}$$

So, just as we can calculate the frequency shift taking the units of mechanical speed $\frac{m}{s}$ into consideration, we can calculate the frequency shift taking into account the units of its equivalent metabolic speed $\frac{kcal}{m}$.

In fact, **Table 3** shows the correlation of the frequency values of the variables studied with the metabolic speed values, according to the variation in the acceleration of the system.

We include these formulas to show that different phenomena such as BMR and mechanical acceleration have the same rate of change. And that is the novelty of our contribution, showing that the same formalization explains the equivalence between BMR and acceleration. This allows us to consider the frequency distribution before and after puberty as a generalization of the Doppler effect [29]-[31].

We also understand that our contribution has certain limitations. For example, the role of the observer in the Doppler effect.

However, a brief comment can help understand the depth of the situation:

The observer is always a complex biological system, like the human being. And if he observes another similar system, or if he observes himself, he will always observe that it approaches the lower frequencies and moves away from the higher ones (inverse Doppler effect) [32].

This will happen at any time in his life, whether during puberty, before or after it. The reason why puberty is taken as a reference is that it is the time of greatest complexity. This means that there will not be in the order of differentiation a new cell line. The oocyte and sperm, they will be the maximum and final expression of growth. It is the end of beginning and the beginning of end: the end of growth and the beginning of aging.

5. Conclusions

Our objectives have been achieved. A frequency distribution has been verified for the variables studied that confirms a clear difference before and after puberty. The highest frequencies are recorded before puberty and the lowest after it. A clear relationship was also verified between the distribution of frequencies and the evolution of BMR/kg dry weight throughout life.

Within the framework proposed by the authors, consideration for the changes in frequency distribution to be considered as an expression of the Doppler effect in biology is permitted.

A generalization of the Doppler effect beyond frequency shifts in mechanical or electromagnetic waves is possible if the principle of equivalence between a mechanically accelerated system and a metabolically accelerated system is taken into account.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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