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RESEARCH ARTICLE

DIFFERENTIAL ENTHALPY, POTENTIAL REVEALER OF CARDIAC POWER AND WORK POWER FROM THE NODAL TISSUE

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ABSTRACT

The blood can be considered as a real fluid flowing in fixed vibrating myocarde canal. Its ejection during the left ventricular contraction is the phenomenon hereby studied. The left ventricle has been taken as a checking volume encompassing one part of aorta. The limit of this thermodynamic system is dotted and situated under endocarde. The blood in this closed ventricle is considered in stationary state. A vent connects the left ventricle to the aorta and the system receives the work power from nodal tissue. The study aims to dial differential enthalpy and to show that it can be used to quantify the cardiac power. The study has been performed on healthy persons, men and women, of Democratic Republic of Congo. The sample of 20.000 cases of healthy persons whose age varies between 13-73 years has been investigated. The blood pressure measurements and calculations are our methodology of work. The figures have been plotted by means of origin 8 program. In each cross section of life the parameter in title has been calculated and correlated to different ages. Also the cardiac power has been calculated at different cardiac frequencies. Interpretations of the results are commented. A new concept of differential enthalpy is introduced in this paper to show that this cute parameter has twofold roll. Firstly it can be used to calculate cardiac power and secondly it can help to evaluate the work power from Keith Flack node. This last assertion constitutes the content of our research on Keith Flack impetus assessment in heart acting.

INTRODUCTION

The blood plasma and the cytoplasm are not the simple liquid media. They contain many molecules belonging to all the possible types and which give to the solution a prominent viscosity particularly in the case of the cytoplasm, considered as a gel. The viscosity is the outcome of the interactions between the solvent molecules and the molecules of dissolved substances. Each movement of a molecule in solution entails friction with the solvent molecules and with the others dissolved molecules. Should the molecule is not spherical, for example should it is a fibrilar protein, the frictions are enhanced and the diffusion is slowed, but also it happens in privileged direction and not in all the directions (Kunyima *et al.,* 2007). The molecules have tendency to diffuse in all the space offered to them and afterwards they move permanently in all directions in the totality of this space with the velocities depending on their size and on the linked water crown they entail. Hence the blood can be considered as a real fluid flowing in fixed vibrating myocarde canal. Its ejection during the left ventricular contraction is the phenomenon hereby studied (Kunyima *et al.,* 2007; JawadMazhar *et al.,* 2015; Longa Kaluba *et al.,* ?; Silbernagl and Despopoulos, 2002). The left ventricle has been taken as a checking volume encompassing one part of the aorta. The limit of this thermodynamic system is dotted and situated under endocarde. The blood in this closed ventricle is considered in stationary state. A vent connects the left ventricle to the aorta and the system receives the work power from nodal tissue. When the left ventricle is filled up by the blood during the diastolic period, this blood is not in displacement and it has a total internal energy $U_{czb} = \mu_{czb} dM_b^+$, where dM_b^+ is the elementary mass of blood received by the system and μ_{czb} is the total

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massic internal energy of the blood (Kunyima *et al.,* 2007; Silbernagl and Despopoulos, 2002; Bejan 1997; Aurora Bakalli *et al.,* 2014; AhlamKadhim, 2015). When the blood pressure in left ventricle becomes higher, a certain amount of blood is poured in aorta, in this case displacement energy should be added in order to take into account the total energy relative to the mass of blood in displacement in the opened system, that means $\mu_{czb}dM_b^+ + P_D\mathrm{v}\ dM_b^+ = (\mu_{czb} + P_D\mathrm{v})dM_b^+ = \quad {}_{czb}dM_b^+$, where $P_D$is the differential pressure at the origin of the left ejection, v is the massic volume of blood and $\quad {}_{czb}$is the massic total enthalpy of blood in displacement. The total internal energy $U_{cz}$of the system defined by the border is then $dU_{czb} = \delta E^+ + \delta Q^+ + \quad {}_{czb}dM_b^+$. It will be demonstrated in our research on Keith Flack impetus assessment in heart acting that $\delta Q^+ = 0$ and $\delta E^+$is the technical work energy received by the system corresponding to the work Power subtitle to be dialed. It can be uptaken that massic total differential enthalpy is equal to $\quad {}_{czb}\left(\frac{\Delta H_D}{M} = \Delta \quad {}_{czb}\right)$ and it will be used to dial work power. Unfortunately the total work power received by the system cannot be calculated because it serves not only to electrical activity of myocarde but also to the blood displacement. Therefore the first part of work power will never be known in recent future perhaps, whereas the last one will be calculated in next paper on the chosen thermodynamic system because the ejected volume of blood is given for healthy persons (Kunyima *et al.,* 2007; Bejan 1997; Lucien Borel, 2011; Jimmy *et al.,* 2013). In the mean time research is continuing in the laboratory to deal with the investment of work power in myocarde electrical activity.

MATERIALS AND METHODS

The sphygmomanometer (Manual, type Aneroid 767 Tycosmurale de Welch Allyn) has been used (Gallavardin, 2014; Simon Vézina, 2015). The observation and calculations (Kunyima *et al.,* 2016; Lusamba, 2016) are our methodology of work. The figures have been plotted by means of origin 8 program. The sample of 20.000 cases of healthy persons whose age varies between 13-73 years has been investigated as follow.

Group 1: 10.000 men with such subgroups

- 1500 men with average of 13 years old.
- 1500 men with average of 23 years old.
- 1500 men with average of 33 years old.
- 1500 men with average of 43 years old.
- 1500 men with average of 53 years old.
- 1500 men with average of 63 years old.
- 1000 men with average of 73 years old.

Group 2: 10.000 women with the same subgroups.

The subgroup of 13 years old contains for example the persons with 13 years and one month, 13 years and few days, 13 years and five months, 13 years and six months. The reasoning is the same for the other ages until 73 years. After fastidious calculations and measures during 2.5 years (April 2013 - December 2015), it has been observed that the minor error was of the same order of magnitude than the implement error. So it has been decided to take the implement error as precision of all the measures of P_D. Consequently the blood pressure of a healthy person of 13 years old will be find around the value mentioned in the table for this age. Exception can of course occur. Hence the age mentioned in the table is for group and individual. It should noted that the study has been performed in Kinshasa precisely in Kinshasa Reference General and Provincial Hospital, in University Clinics of Kinshasa and in our Laboratory (LACOPA). The procedure of experimentation has remained the same (Kunyima *et al.,* 2016). The following equation has been used for the blood which is the real fluid (Kunyima *et al.,* 2007; Lucien Borel, 2011; Jean-Noël, 2005) in order to verify the hypothesis in title.

$$\int dH = \int CpdT + \int \left[V \quad T\left(\frac{\partial V}{\partial T}\right)_P\right] dT$$

Human body temperature is constant (Kunyima *et al.,* 2007; Silbernagl, 2002).

So dT= 0 and $\left(\frac{\partial V}{\partial T}\right)_P = 0$

$$\int dH = \int_1^2 Vdp$$

The ejected volume at left ventricle contraction is constant
(80 ml) (Kunyima *et al.,* 2007; Silbernagl, 2002).

$$\Delta H_D = \mathrm{V}(P_2 \quad P_1) = -\mathrm{V}(P_1 \quad P_2) = -\mathrm{V}(P_s \quad P_d)$$

$P_1 = P_s$ = Systolic pressure.
$P_2 = P_d$= Diastolic pressure.

It has been decided to call this energy total differential enthalpy because it depends on differential pressure ($P_D = P_s - P_d$). This parameter can be used to calculate cardiac Power ($P_c = \quad H_D.fc$), where f_c is the cardiac frequency and the minus sign means that the system has given this power. In the continuation it will be relinquished specially in the figures. The same reasoning is proposed for ΔH_D. Converted in total massic differential enthalpy (h_{czb}) it becomes the energy accompanying the blood movement through the virtual border between left ventricle and aorta.

Indeed $\Delta H_D = +\frac{M}{\rho}(P_d - P_s)$
$h_{czb} = \frac{\Delta H_D}{M} = +\frac{1}{\rho}(P_d - P_s)$

M is the blood mass and ρ is the blood volumic mass.

$\Delta h_{czb}$is the variation of the total massic differential enthalpy ($h_{czb} = h + \frac{C^2}{2} + gz$).

When a thermodynamic system is a seat of work transfers, heat transfers and mass transfers, a distinction should be made between global work energy received by the system A^+ and technical work energy E^+ received only at the mobile parts of the system (Lucien Borel. 2011),

$\delta A^+ = \delta E^+ + \delta E_b^+$
δE^+ is the technical energy at mobile parts.
$\delta E_b^+$is the energy at the blood.

The total internal energy U_{cz} of the system can be written:

$dU_{cz} = \delta A^{+} + \delta Q^{+}$, where $Ucz = U + \frac{MC^2}{2} + Mgz$; $u_{cz} = u + \frac{C^2}{2} + gz$
$dU_{cz} = \delta E^{+} + \delta Q^{+} + \delta E_b^{+}$

where $\delta E_b^{+} = \delta U_{czb} = u_{czb}.dM_b^{+}$ (for stationary blood).

$\delta E_b^{+} = F_b C_b dt = P_D S_b C_b dt$ (for blood in movement), where C_b is the mean velocity of the blood in the section S_b; P_b is blood pressure through the S surface = P_D.

For the stationary blood $dUcz = \delta E^{+} + \delta Q^{+} + u_{czb}.dM_b^{+}$
For the blood in displacement $\dot{M}_b^{+} = \frac{dM_b^{+}}{dt} = \frac{C_b.S_b}{v_b}$, where v_b is massic volume of blood through the S_b surface: $v_b \frac{dM_b^{+}}{dt} = S_b C_b$.

This last relation in the expression of the blood in movement gives the contribution of the blood in displacement to its energy:

$$\delta E_b^{+} = P_D v_b \frac{dM_b^{+}}{dt} dt = P_D v_b dM_b^{+}$$

Globally it can be written

$$\delta E_b^{+} = u_{czb}.dM_b^{+} + P_D v_b dM_b^{+} = (u_{czb} + P_D v_b) dM_b^{+}$$

$$\delta E_b^{+} = h_{czb} dM_b^{+}$$

$$dU_{cz} = \delta E^{+} + \delta Q^{+} + h_{czb} .dM_b^{+}$$

In the calculation the kinetic energy and the potential energy will be neglected.

RESULTS AND DISCUSSION

Epidemiologic studies have shown clearly that the cardiac frequency is a risk factor of morbidity and cardiovascular death; more for men than for women (Palatini *et al.,* 2006). The Impact of the cardiac frequency remains indeed meaningful after adjusting on the age and many factors of cardiovascular risk such as body mass index, the glycaemia, the cholesterol, the triglycerides and arterial pressure. The effect of high cardiac frequency has been found as well in the hypertensive group as in the healthy persons even though in the case of the hypertensive the impact is high. It has been observed that for the women the effect of cardiac frequency is weak (Benetos *et al.,* 2003). It is generally admitted that the cardiac frequency decreases with the age. Indeed the most observed cardiovascular manifestation for the old persons is the decrease of maximum cardiac frequency with the effort. On the contrary, at the rest, the decrease of the cardiac frequency with the age is less clean. Study has been led on a large fraction of French population, the decrease of the cardiac frequency with the age has not been observed as it is shown in figure 1 where it can be seen that on a very large fraction of population, the cardiac frequency is almost constant between 15 and 75 years (Morcet *et al.,* 1999). Moreover the women have a cardiac frequency more of almost 4 bpm than man cardiac frequency. A difference of cardiac frequency between genders on this French population has been reported.

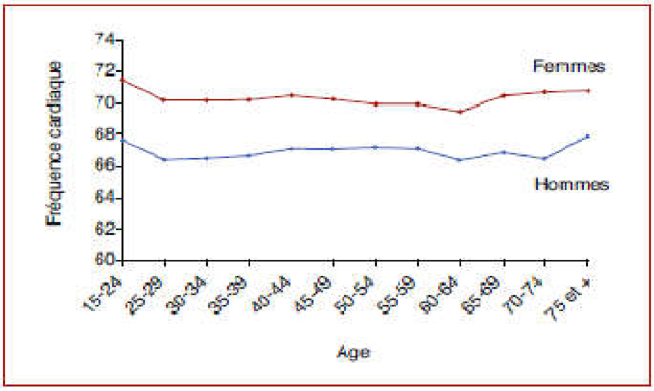

Fig. 1. Cardiac frequency (f_c) as a function of gender and age

It has been pointed out that the women cardiac frequencies are higher than the men cardiac frequencies of about 5-7bpm (Morcet *et al.,* 1999; Palatini and Julius, 1997). In this paper the study of cardiac frequency between genders has not been performed.It has been however observed that in each cross section of live all the cardiac frequencies have been found between 60-100 bpm. This scattering of cardiac frequencies in our population of Democratic Republic of Congo can be explained in short by the lack of informations on nutrition science in general and the absence of the sporting activities. The insufficiency of better medical taking charge of population and its growing impoverishment are also at the origin of the situation (Lusamba, 2016; Pamplona Roger, 2000; KabeleNgiefu *et al.,* 2015). Any way in this work it has been decided to make tables and figures with systolic and diastolic pressures measured at different cardiac frequencies found in each gender and each cross section of life. It is useful before continuing to remember the representation of the heart acting in the plane as it can be seen in figure 2 (this is a modelisation). This figure is made in Laboratory of Physical Organic and Food Chemistry (LACOPA), Faculty of Sciences, University of Kinshasa, Democratic Republic of Congo. It should be branded on the memory that this figure is done in the teaching purpose. The tables 1 and 2 are relative to healthy men and healthy women of 13 years old until 73 years old with a discard of ten years (one generation). It can be seen in this table that at a given ΔH_D the cardiac power increases linearly with increasing cardiac frequency as it is shown in figure 2 (Lusamba, 2016; Jean-Noël Foussardet Edmond Julien, 2015). When the cardiac power is followed as a function of age at a given cardiac frequency, the figures exhit all of them the decrease of the cardiac power from 13-43 years; stagnation between 43-53 years and afterwards an increase until 73 years (see for example figure 4). The same pace is followed by the differential pressure whose the relation with cardiac power has been established (Lusamba, 2016). Note that the heart acting is better should the given cardiac power and its yield are low. ΔH_D also decreases with the encreaising age, becomes stagnant between 33-43 years and afterwards increases as it is observed in figure 5. The table 2 shows the differential enthalpy values and the cardiac power at different cardiac frequencies for the women at the same ages (13-73). When one has a look to this table the observation is the same. The cardiac power is correlated to cardiac frequency as it is shown in figure 6. It can be seen the difference with figure 3 in the behavior of age women.

Table 1. Vital parameters for men

Age (years)	P_s *(mm Hg)*	P_d *(mm Hg)*	P_D ± P_D *(mm Hg)*	H_D ± H_D *(J)*	*Fc (bpm)*	*Pc ± ΔPc (W)*
13	118	68	50 ± 0,5	- 0,526 ± 0,005	60	-0,526 ± 0,005
					65	-0,570 ± 0,005
					70	-0,614 ± 0,006
					75	-0,657 ± 0,006
					80	-0,701 ± 0,007
					85	-0,745 ± 0,007
					90	-0,789 ± 0,008
					95	-0,833 ± 0,008
					100	-0,877 ± 0,008
23	123	75	48 ± 0,5	-0,505 ± 0,005	60	-0,505 ± 0,005
					65	-0,547 ± 0,005
					70	-0,589 ± 0,006
					75	-0,631 ± 0,006
					80	-0,673 ± 0,007
					85	-0,715 ± 0,007
					90	-0,757 ± 0,008
					95	-0,800 ± 0,008
					100	-0,842 ± 0,008
33	120	73	47 ± 0,5	-0,495 ± 0,005	60	-0,495 ± 0,005
					65	-0,536 ± 0,005
					70	-0,577 ± 0,006
					75	-0,618 ± 0,006
					80	-0,660 ± 0,007
					85	-0,701 ± 0,007
					90	-0,742 ± 0,008
					95	-0,783 ± 0,008
					100	-0,825 ± 0,008
43	122	75	47 ± 0,5	-0,495 ± 0,005	60	-0,495 ± 0,005
					65	-0,536 ± 0,005
					70	-0,577 ± 0,006
					75	-0,618 ± 0,006
					80	-0,660 ± 0,007
					85	-0,701 ± 0,007
					90	-0,742 ± 0,008
					95	-0,783± 0,008
					100	-0,825 ± 0,008
53	132	82	50 ± 0,5	-0,526±0,005	60	-0,526 ± 0,005
					65	-0,570 ± 0,005
					70	-0,614 ± 0,006
					75	-0,657 ± 0,006
					80	-0,701 ± 0,007
					85	-0,745 ± 0,007
					90	-0,789 ± 0,008
					95	-0,833 ± 0,008
					100	-0,877 ± 0,008
63	140	87	53 ± 0,5	-0,557±0,005	60	-0,557 ± 0,005
					65	-0,604 ± 0,005
					70	-0,650 ± 0,006
					75	-0,697 ± 0,006
					80	-0,743 ± 0,007
					85	-0,790 ± 0,007
					90	-0,836 ± 0,008
					95	-0,883 ± 0,008
					100	-0,929 ± 0,008
73	142	81	61 ±0,5	-0,642±0,005	60	-0,642 ± 0,005
					65	-0,695 ± 0,005
					70	-0,749 ± 0,006
					75	-0,802 ± 0,006
					80	-0,856 ± 0,007
					85	-0,909 ± 0,007
					90	-0,963 ± 0,008
					95	-1,016 ± 0,008
					100	-1,070 ± 0,009

Table 2. Vital parameters for women

Age (years)	P_{syst} (mm Hg)	P_{dias} (mm Hg)	$P_D \pm \Delta P_D$ (mm Hg)	$\Delta H_D \pm \Delta\Delta H_D$ (J)	fc (bpm)	Pc ± ΔPc (W)
13	117	71	46 ± 0,5	-0,484 ± 0,005	60	-0,484 ± 0,005
					65	-0,524 ± 0,006
					70	-0,564 ± 0,006
					75	-0,605 ± 0,006
					80-	-0,645 ± 0,007
					85	-0,685 ± 0,007
					90	-0,726 ± 0,008
					95	-0,766 ± 0,008
					100	-0,807 ± 0,009
23	118	73	45 ± 0,5	-0,473±0,005	60	-0,473 ± 0,005
					65	-0,513 ± 0,006
					70	-0,552 ± 0,006
					75	-0,592 ± 0,006
					80	-0,631 ± 0,007
					85	-0,671 ± 0,007
					90	-0,710 ± 0,008
					95	-0,750 ± 0,008
					100	-0,789 ± 0,009
33	118	72	46 ± 0,5	-0,484 ± 0,005	60	-0,484 ± 0,005
					65	-0,524 ± 0,006
					70	-0,564 ± 0,006
					75	-0,605 ± 0,006
					80	-0,645 ± 0,007
					85	-0,685 ± 0,007
					90	-0,726 ± 0,008
					95	-0,766 ± 0,008
					100	-0,807 ± 0,009
43	131	81	50 ± 0,5	-0,526 ± 0,005	60	-0,526 ± 0,005
					65	-0,570 ± 0,005
					70	-0,614 ± 0,006
					75	-0,657 ± 0,006
					80	-0,701 ± 0,007
					85	-0,745 ± 0,007
					90	-0,789 ± 0,008
					95	-0,833 ± 0,008
					100	-0,877 ± 0,008
53	135	83	52 ± 0,5	-0,547 ± 0,005	60	-0,547 ± 0,005
					65	-0,592 ± 0,006
					70	-0,638 ± 0,006
					75	-0,684 ± 0,006
					80	-0,729 ± 0,007
					85	-0,775 ± 0,007
					90	-0,821 ± 0,008
					95	-0,866 ± 0,008
					100	-0,912 ± 0,009
63	138	87	51 ± 0,5	-0,536 ± 0,005	60	- 0,536 ± 0,005
					65	-0,581 ± 0,006
					70	-0,626 ± 0,006
					75	-0,671 ± 0,006
					80	-0,715 ± 0,007
					85	-0,760 ± 0,007
					90	-0,805 ± 0,008
					95	-0,85 ± 0,008
					100	-0,894 ± 0,009
73	140	89	51 ± 0,5	-0,536 ± 0,005	60	-0,536 ± 0,005
					65	-0,581 ± 0,006
					70	-0,626 ± 0,006
					75	-0,671 ± 0,006
					80	-0,715 ± 0,007
					85	-0,760 ± 0,007
					90	-0,805 ± 0,008
					95	-0,85 ± 0,008
					100	-0,894 ± 0,009

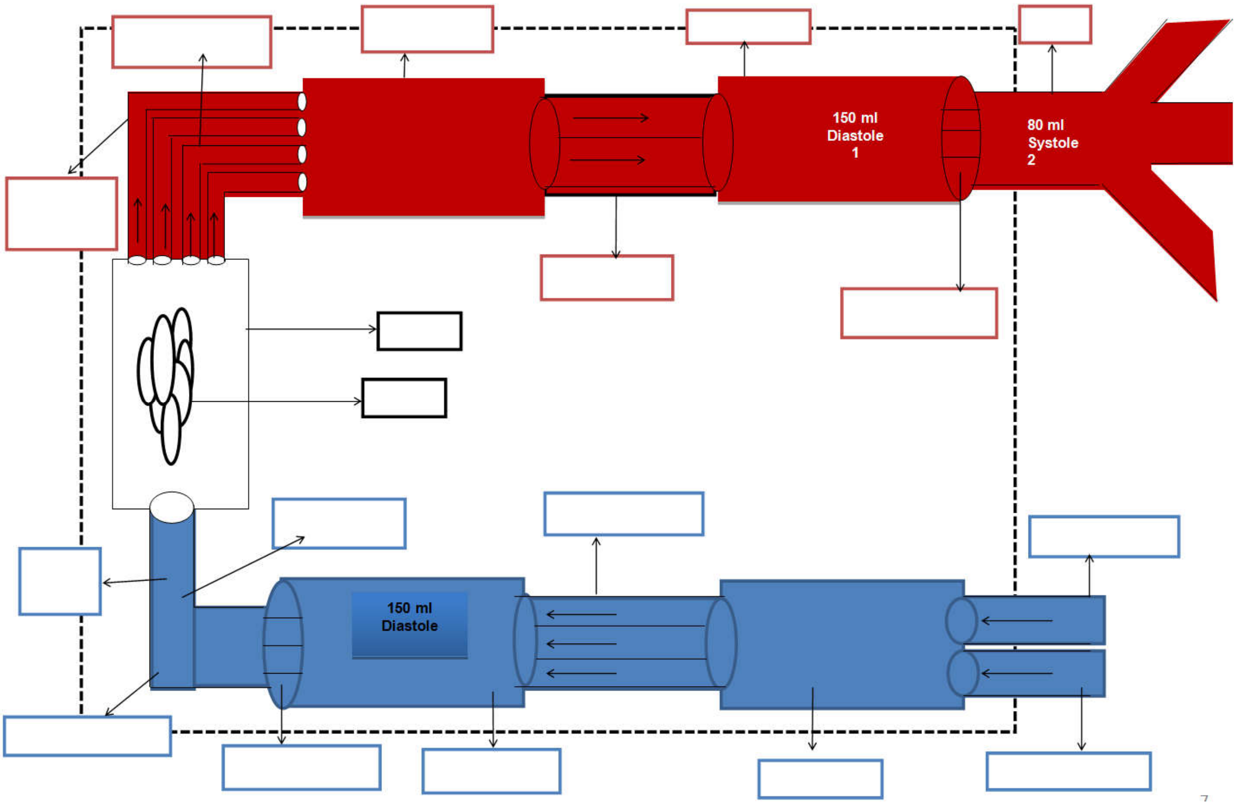

Fig. 2.

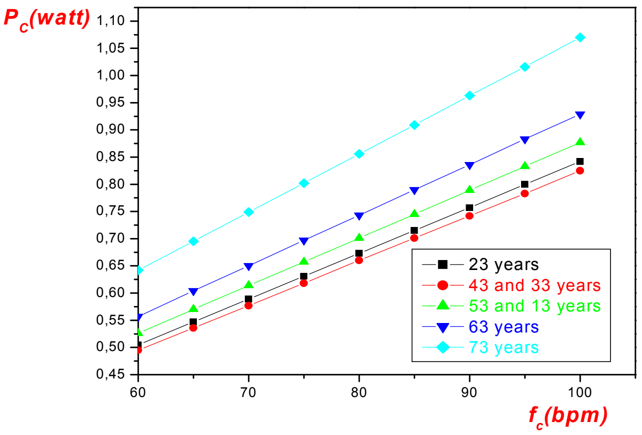

Fig. 3.Cardiac power (P_C) versus cardiac frequency (f_c)

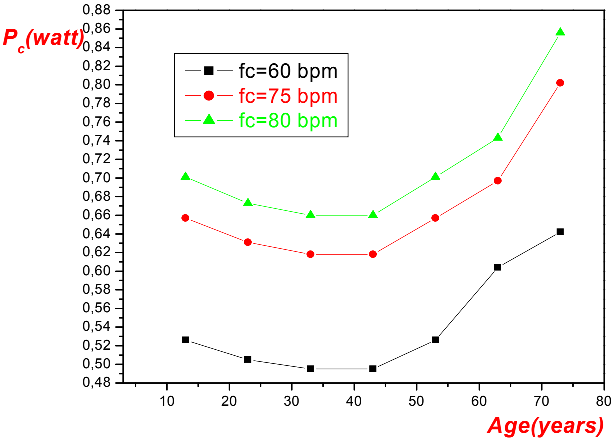

Fig. 4. Cardiac power (P_C) versus Age

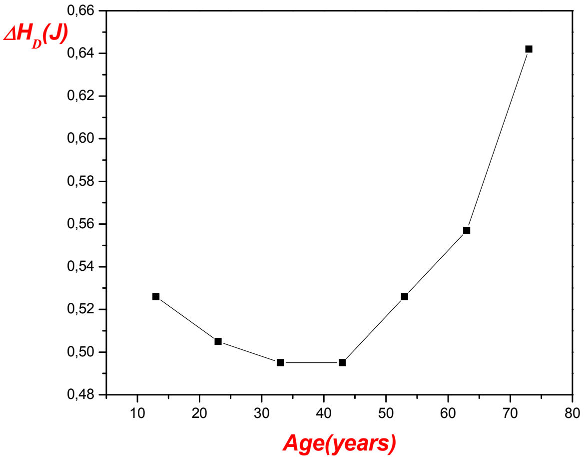

Fig. 5. Variation of the total differential enthalpy(H_D) versus Age

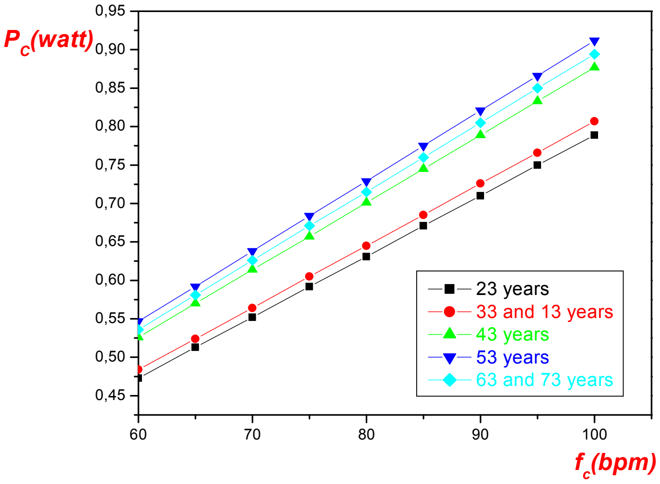

Fig. 6. Cardiac power (P_C) versus cardiac frequency (f_c)

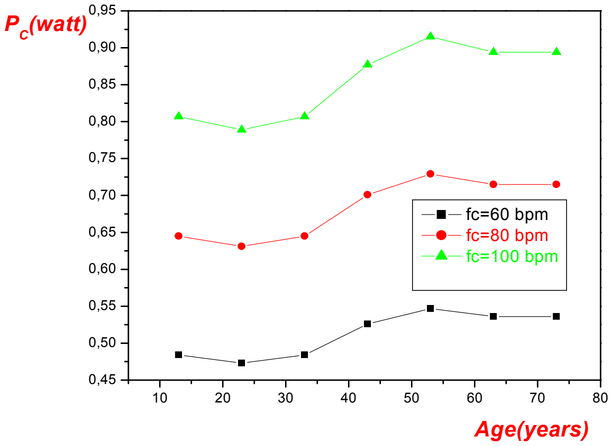

Fig. 7. Cardiac power (P_C) versus Age

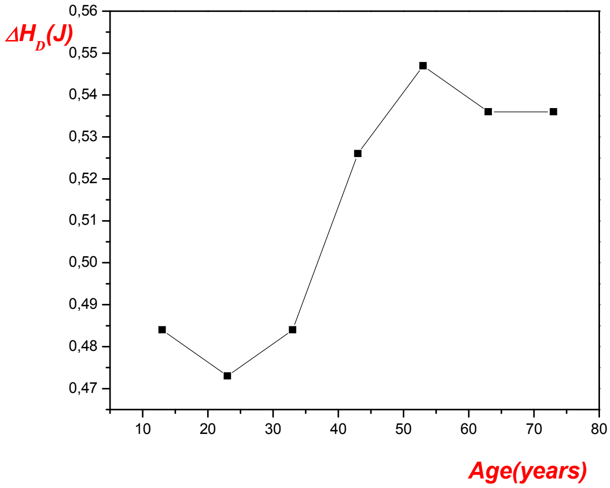

Fig. 8. Variation of the total differential enthalpy (H_D) versus Age

The cardiac power as a function of age at a given cardiac frequency shows the following pace. When this is compared with the man the behavior is quite different. When $\Delta H_D$is followed as a function of age, it is observed in this group the curve quite different compared to men as it can be remarked in figure 8. There is physiological difference between men and women. $P_D$for men is higher than for women except at the ages 43 of and 53 years where the inversion is observed. Comment is the same with ΔH_D.

Conclusion

The overall purpose is to present the new concept of differential pressure allowing to calculate cardiac power and through which the work power from Keith-Flack node will be deemed (Kunyima *et al.,* 2007; Lucien Borel, 2011). ΔH_Ddoes not depend on cardiac frequency, it depends on age. For men the value of ΔH_D at 13 years (0.526 J) after decreasing with age is reached again at 53years (0.526 J) and increases until 73 years. For women however the value of ΔH_D at 13 years (0.484 J) after decreasing with age is reached earlier at 33 years (0.484 J) and increases until 63 years where it remains constant until 73 years showing thus men and women are really physiologically quite different (Morcet *et al.,* 1999). Also men ΔH_D values are higher than women ΔH_D values except at 43 and 53 years old where inversion is observed meaning that at a certain moment of life the inversion can occur between two genders. The observation is the same with respect to the cardiac power at given cardiac frequency.

Abbreviations

Variation of the total differential enthalpy (H_D); Cardiac frequency (f_c); Total internal energy (U_{cz}); Variation of the total massic differential enthalpy (**h_{czb}**); Total massic internal energy (μ_{czb}); Cardiac power (P_C); Differential pressure (P_D).

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