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RESEARCH ARTICLE

THERMOEXERGETIC STUDY OF CARDIAC SYSTEM: CASE OF SOME HEALTHY WOMEN AND SOME HEALTHY MEN OF DEMOCRATIC REPUBLIC OF CONGO

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ABSTRACT

The heart rhythm is beneath the supervision of the nodal tissue which encompasses the Keith flack node, the AschoffTawara node and the Hiss bundle. Keith flack node, in the right auricle wall emits an impetus that propagates. In 1/10 of second the influx reaches the AschoffTawara node and after another 1/10 of second, the influx reaches the Hiss bundle leading it to the ventricles in order to entail their contractions. Can it be said that this impetus from Keith flack node has undergone an exergetic loss when arrived to ventricles contractions step? No answer for the moment. But having seen the time scale of transfer it can be approximated that the influx is integrally transmitted. One of its parts has been used for the myocarde electrical activity and one part for the blood motion. This last part is concerned in this paper. The total massic differential enthalpy has been issued as a prominent parameter making possible the assessment of the Keith flack impetus. In this paper, thermoexergetic parameters such as work power $[E^{+}]$, effective work power $[E_e^{+}]$, exergetic loss *[L]*, exergetic yield $[\eta_{ex}]$ and massic entropy variation [s] have been determined. 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 exergetic yield and the massic entropy variation have been found constant while the work power, the effective work power and the exergetic loss are increasing with the increasing cardiac frequency. Also the small change of those parameters with the age has been noted as well for the men as for the women subtitle. KUNYIMA formula has been proposed to calculate the work power and its values are expressed in Kys (KUNYIMA units). Results are hereby discussed.

INTRODUCTION

The heart rhythm is beneath the supervision of the nodal tissue which encompasses the Keith flack node, the AschoffTawara node and the Hiss bundle. Keith flack node, in the right auricle wall emits an impetus that propagates. In 1/10 of second the influx reaches the AschoffTawara node and after another 1/10 of second, the influx reaches the Hiss bundle leading it to the ventricles in order to entail their contractions. Can it be said that this impetus from Keith flack node has undergone an exergetic loss when arrived to ventricles contractions step? No answer for the moment. But having seen the time scale of transfer it can be approximated that the influx is integrally transmitted. One of its parts has been used for the myocarde electrical activity and one part for the blood motion. This last part is concerned in this paper (Frayon, 2012; Leonard *et al.,* 2007; Lusamba S. Ntumba2016). The human body is an opened thermodynamic system which exchanges with the outside heat and materials. Seeing that the biological systems are essentially isothermics, on part of this heat, coming from exergonic biochemical reactions, is used under couplage form to help vital processes realization such as the muscular contractions, the endergonic reactions, nervous conductions and active transfers. One part of this heat is poured in the atmosphere. It is generally recognized that the heat energy (Q_a), transferred between the system and the atmosphere is neither useful nor spent, since it does not present any interest for the experts. That means it

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does not have value when it is supplied and it is gratis when it is consumed (Kunyima *et al.,* 2007; Lucien Borel *et al.,* 2011). At this point of view, the cardiac system can be considered as a system with work, adiabatic, opened, in permanent regime (succession of diastolic and systolic periods), constituted of fixed vibrational and isolated canal in which the blood is permanently flowing with a mass debit M. Note that the cardiac system is a set of small thermodynamic systems in which the right heart acting and the left heart acting are synchronized and the right heart blood debit is equal to the left heart blood debit. The plenty left ventricle with one part of the aorta including the vent in between have been chosen as our checking volume or our thermodynamic system. The system receives work power, E^{+}, from left ventricle contraction and induces the blood motion through the vent towards the aorta (Lucien Borel *et al.,* 2011; Boutouyrie *et al.,* 2010; Abdulsalam Mahmoud Algamal, 2016; Adrian Bejan, 1997).

MATERIALS AND METHODS

The sphygmomanometer (Manual, type Aneroid 767 Tycos mural de Welch Allyn) has been used (Gallavardin *et al.,* 2014; Didier, 2015). The calculations have been made on the sample of 20.000 cases of healthy persons whose age varies between 13-73 years. In group 1, 10.000 men have been selected according to the following repartition. 1500 men (13 years old); 1500 men (23 years old); 1500 men (33 years old);1500 men (53 years old); 1500 men (63 years old) and 1000 men (73 years old). The second group has been constituted of women with the same repartition. The relation giving the energetic and the exergetic balances sheet have been used (Kunyima *et al.,* 2007; Lucien Borel *et al.,* 2011; Jean-Noël Foussard, 2005).

$\sum[E_e^+] + \sum[Q_i^+] + \sum[W_e^+] = \sum[E_e^-] + \sum[Q_i^-] + \sum[W_e^-]$ ….. (1)

$\sum[E_e^+] + \sum[E_q^+] + \sum[E_W^+]L = \sum[E_e^-] + \sum[E_q^-] + \sum[E_W^-]$ ….. (2)

Where $E_e^+ = E^+ + P_a \quad V = E^+ + P_a \frac{dV}{dt}$ = effective work power received by the system ………………………………….. (3)

P_a = atmospheric pressure

Q_i^+ = heart power received by the system at T_i temperature

$W_e^+ = \sum[\ _{czb}\, M_b^+]\frac{dU_{ecz}}{dt}$ = effective transformation power received by the system ………………………………….. (4)

M_b^+ = blood mass debit received by the system

$E_q^+ = \int \theta\delta Q^+$ = heart co-power received by the system ……. (5)

$\theta = 1 \ \frac{T_a}{T_i}$ = Carnot factor ………………………………….. (6)

T_a = atmospheric temperature

$E_W^+ = \sum[\ _{czb}\, M_b^+]\frac{dJcz}{Dt}$ = transformation co-power received by the system.

$k_{cz} = \ _{cz}\, T_a s$ = *massic total Coenthalpy where s is massic entropy.*

$J_{cz} = U_{ecz} T_a s = U_{cz} + P_a V \ T_a s$ = *total coenergy*

$L = T_a \frac{\delta s^i}{dt} \geq 0$ *exergetic loss in power where* S^i *is internal entropy.*

The studied thermodynamic system can be represented as follow:

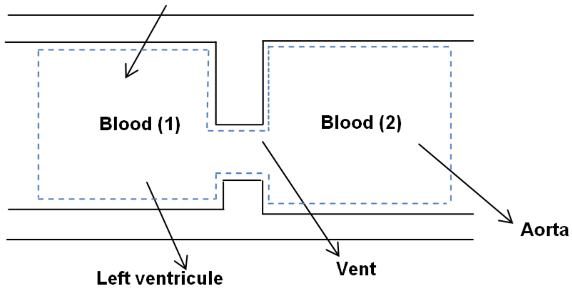


Fig. 1. Studied thermodynamic system

For this permanent system $\frac{dU_{ecz}}{dt} = 0; \frac{dJcz}{dx} = 0$

The exergetic balance sheet is

$E_e^+ \quad L = E_w^-$ ………………………………….. (7)

And the energetic balance sheet is

$E_e^+ = W^-$ ………………………………….. (8)

According to equation (4)

$W_e^+ = W^+ = \sum[\ _{czb}\, M_b^+] = M_b^+[\ _{cz(1)} \quad _{cz(2)}]$

$= M_b^+[\ _{cz(2)} \quad _{cz(1)}]$

$= M_b^+ \ _{czb} = M_b^+ \frac{1}{\rho}(P_d \quad P_s)$

$E_e^+ = W^- = M_b^+ \frac{1}{\rho}(P_d \quad P_s)$ with $M_b^+ = \rho V$

$E_e^+ = V(P_d \quad P_s) = V f_C (P_s \quad P_d)$ ………………. (9)

Where V=80 ml, the ejected volume of blood (Silbernagl and Despopoulos, 2002) and f_c is the cardiac frequency. According to equation (3), equation (9) becomes

$E^+ + P_a (V_2 \quad V_1) = V f_c (P_s \quad P_d)$

$E^+ = V f_c (P_s \quad P_d) + P_a (V_1 \quad V_2)$

$E^+ = V f_c (P_s \quad P_d) + P_a f_c (V_1 \quad V_2)$ ....………. (10)

V_1 = 150ml of blood, V_2 = V= 80ml of blood ejected in aorta

$V_1 \quad V_2$ = 70ml of blood (Frayon, 2012; Silbernagl and Despopoulos, 2002).

This last equation (10) has been called "KUNYIMA Formula". E ^+will be expressed in watt Keith Flack to indicate the origin of this power. It has been decided in laboratory, in order to honour the name of Dr. Anaclet KUNYIMA BADIBANGA, Ordinary Professor at University of Kinshasa who proposed this expression, to give to this calculated work power the unit KUNYIMA (Ky→pl. Kys).

So 1Ky = 1 Watt Keith Flack
2 Kys = 2 W Keith Flack
1 kW Keith Flack = 1000 W Keith Flack = 1000Kys

Using the exergetic balance sheet nice informations can be obtained about exergetic loss, entropy, coenthalpy and exergetic yield.

Indeed

$E_e^+ \quad L = E_W^-$

$E_W^+ = \sum\left[k_{Czb} M_b^+\right] \quad \frac{dJ_{Cz}}{dt}$;

$\frac{dJ_{Cz}}{dt} = 0$ (Permanent regime)

$E_W^+ = \sum\left[k_{Czb} M_b^+\right] = \sum\left[k_b M_b^+\right]$

The variation of kinetic energy and potential energy is neglected.

$E_W^+ = M_b^+ \sum[k_{b1} \quad k_{b2}]$

$= M_b\ [(\ _1 \quad T_a s_1) \quad (\ _2 \quad T_a s_2)]$

$= M_b\ [(\ _1 \quad\ _2) + T_a(s_2 \quad s_1)]$

$E_W^+ = M_b(\ _1 \quad\ _2) + M_b T_a(s_2 \quad s_1)$

$E_W^- = M_b(\ _2 \quad\ _1) \quad M_b T_a\ (s_2 \quad s_1)$

$L = E_e^+ \quad E_W^-$

$L = E^+ + P_a\ (V_2 \quad V_1) \quad [M_b(\ _2 \quad\ _1) \quad M_b T_a(s_2 \quad s_1)]$

$L = E^+ + P_a\ (V_2 \quad V_1) \quad M_b(\ _2 \quad\ _1) + M_b T_a(s_2 \quad s_1)$

So the exergetic yield is

$\eta_{ex} = \frac{E_W^-}{E_e^+} = 1 \quad \frac{L}{E_e^+} = \frac{P_c}{E^+}$

Lcan be obtained from the following relation

$L = (1 \quad n_{ex})\ E_e^+$

$s_2 \quad s_1$has been calculated from (12)

$s_2 \quad s_1 = \frac{L - E_e^+ - Vf_c\ (P_s - P_d)}{\rho V f_c T_a}$

ρ= 1, 06 g/ml = mean density of blood (Kunyima *et al.,* 2007).

T_a= 27°C = 300°K

Note that the implement error has been taken as the precision of P_D. The precisions $\quad L$, E^+ and $\quad$ s have been calculated respectively from the following relations

$L = \left|\frac{E_e^+}{E_e^+}\right| |L|$

$E^+ = \left|\frac{Vf_c \quad P_D}{Vf_c P_D + P_a f_c \quad V}\right| |E^+|$

With $V = V_1 \quad V_2$

$s = \left|\frac{L + \ E_e^+ + Vf_c \ \ P_D}{L - E_e^+ - Vf_c P_D}\right| |s_2 \quad s_1|$

RESULTS AND DISCUSSION

The table 1 gives the thermoexergetic parameters for healthy women and the table 2 the thermoexergetic parameters for healthy men. In those tables the column P_c, E_e^+, L and s have the negative values. With respect to values of P_c, E_e^+, L, the system receives negative values. That means the system gives positive energy, it is the energy lost by the system. In each table there is identity between P_c column and E_e^+ column. When one has a look to the table 1, it can be observed that in each cross section of life the cardiac yield is weak and remains constant. Also it does not depend on cardiac frequency; it depends slightly on age for women since it decreases globally with the increasing age until 23 years old, increases until 53 years old and decreases afterwards in remaining constant until 73 years old. Indeed it has been reported that each biological system, which is not in transient state, acts at constant yield (Cherruault Y. Biomathématiques, 1983; Bénazeth *et al.,* 2004; Fliers *et al.,* 2003; Kunyima *et al.,* 2016). The observation of table 2 shows the decrease of exergetic yield from 13 to 33 years old, stagnation between 33-43 years old and afterwards an increase until 73 years old for men. In comparison it can be generally said that the man exergetic yield is higher than the woman exergetic yield at the same age even though the inversion sometimes can occur as it can be seen here at 43 years old and at 53 years old where the woman exergetic yield is higher than the man exergetic yield. The figure 1 giving cardiac yield versus age testifies this assertion. The cardiac yield is a very important parameter because it shows the performance and the longevity of the heart. Note its normal limit values for men and women subtitle in each cross section of life: 7,25≤ η_{ex} ≤ 8,48 for women (13-73) and 7,61 ≤ η_{ex} ≤ 10,09 for men (13-73)

The lower limits do not correspond necessarily to the lower ages and things are the same for upper limits. With respect to work power (E^+), it can be observed that it increases when the cardiac frequency increases in each cross section of life as well for men as women in the interval of frequencies of 60-100. At a given cardiac frequency, E^+ increases for women from 13-23 years old, decreases until 53 years old and afterwards increases in remaining constant until 73 years old. For the men however the behavior of E^+ is quite different. In this last case indeed, at a given cardiac frequency, E^+ increases from 13 to 33 years old, stagnation is observed between 33-43 years old, and afterwards the decrease until 73 years old as it can be seen in figures 2. Despite the inversion of E^+ values observed at 43 and 53 years old between men and women, it can be pointed out that generally the work power (E^+) of women is somewhat high at a given cardiac frequency as it can be seen in this figure 2.

Table 1.Thermoexergetic parameters for healthy women (13-73 years old)

Age (years)	P_s (mmHg)	P_d (mmHg)	$P_D \pm P_D$ (mmHg)	$H_D \pm H_D$ (J)	f_c (bpm)	$P_c \pm P_c$ (W)	$E^+ \pm E^+$ (Kys)	η_{ex} (%)	$E_e^+ \pm E_e^+$ (W)	$L \pm L$ (W)	s ($J\,kg^{-1}K^{-1}$)
					60	-0,484±0,005	6,516±0,005	7,43	-0,484±0,005	-0,448±0,005	-0,0200±0,0006
					65	-0,524±0,006	7,059±0,006	7,42	-0,524±0,006	-0,485±0,006	-0,0200±0,0006
					70	-0,564±0,006	7,602±0,006	7,42	-0,564±0,006	-0,522±0,006	-0,0200±0,0006
13	117	71	46±0,5	0,484±0,005	75	-0,605±0,006	8,145±0,006	7,43	-0,605±0,006	-0,560±0,006	-0,0200±0,0006
					80	-0,645±0,007	8,688±0,006	7,42	-0,645±0,007	-0,597±0,006	-0,0200±0,0006
					85	-0,685±0,007	9,231±0,007	7,42	-0,685±0,007	-0,634±0,006	-0,0200±0,0006
					90	-0,726±0,008	9,774±0,008	7,43	-0,726±0,008	-0,672±0,006	-0,0200±0,0006
					95	-0,766±0,008	10,317±0,008	7,43	-0,766±0,008	-0,709±0,007	-0,0200±0,0006
					100	-0,807±0,009	10,860±0,009	7,43	-0,807±0,009	-0,747±0,008	-0,0200±0,0006
					60	-0,473±0,005	6,526±0,005	7,25	-0,473±0,005	-0,439±0,005	-0,0200±0,0006
					65	-0,513±0,006	7,070±0,006	7,25	-0,513±0,006	-0,476±0,006	-0,0200±0,0006
					70	-0,552±0,006	7,614±0,006	7,25	-0,552±0,006	-0,512±0,006	-0,0200±0,0006
					75	-0,592±0,006	8,158±0,006	7,25	-0,592±0,006	-0,549±0,006	-0,0200±0,0006
					80	-0,631±0,007	8,702±0,007	7,25	-0,631±0,007	-0,585±0,007	-0,0200±0,0006
23	118	73	45±0,5	0,473±0,005	85	-0,671±0,007	9,246±0,007	7,25	-0,671±0,007	-0,622±0,007	-0,0200±0,0006
					90	-0,710±0,008	9,789±0,008	7,25	-0,710±0,008	-0,659±0,008	-0,0200±0,0006
					95	-0,750±0,008	10,333±0,008	7,25	-0,750±0,008	-0,696±0,008	-0,0200±0,0006
					100	-0,789±0,009	10,877±0,009	7,25	-0,789±0,009	-0,732±0,008	-0,0200±0,0006
					60	-0,484±0,005	6,516±0,005	7,43	-0,484±0,005	-0,448±0,005	-0,0200±0,0006
					65	-0,524± 0,006	7,059±0,006	7,42	-0,524± 0,006	-0,485±0,006	-0,0200±0,0006
					70	-0,564±0,006	7,602±0,006	7,42	-0,564±0,006	-0,522±0,006	-0,0200±0,0006
					75	-0,605±0,006	8,145±0,006	7,43	-0,605±0,006	-0,560±0,006	-0,0200±0,0006
					80	-0,645±0,007	8,688±0,007	7,42	-0,645±0,007	-0,597±0,007	-0,0200±0,0006
33	118	72	46±0,5	0,484±0,005	85	-0,685±0,007	9,231±0,007	7,42	-0,685±0,007	-0,634±0,007	-0,0200±0,0006
					90	-0,726±0,008	9,774±0,008	7,43	-0,726±0,008	-0,672±0,008	-0,0200±0,0006
					95	-0,766±0,008	10,317±0,008	7,43	-0,766±0,008	-0,709±0,008	-0,0200±0,0006
					100	-0,807±0,009	10,860±0,009	7,43	-0,807±0,009	-0,747±0,008	-0,0200±0,0006
					60	-0,526±0,005	6,474±0,005	8,13	-0,526±0,005	-0,483±0,005	-0,0200±0,0006
					65	-0,570±0,006	7,013±0,005	8,13	-0,571±0,005	-0,525±0,005	-0,0200±0,0006
					70	-0,614±0,006	7,553±0,005	8,13	-0,614±0,005	-0,564±0,005	-0,0200±0,0006
43	131	81	50±0,5	0,526±0,005	75	-0,657±0,006	8,092±0,006	8,12	-0,657±0,006	-0,604±0,006	-0,0200±0,0006
					80	-0,701±0,007	8,632±0,007	8,12	-0,701±0,007	-0,644±0,007	-0,0200±0,0006
					85	-0,745±0,007	9,171±0,007	8,12	-0,745±0,007	-0,685±0,007	-0,0200±0,0006
					90	-0,789±0,008	9,711±0,008	8,12	-0,789±0,008	-0,725±0,008	-0,0200±0,0006
					95	-0,833±0,008	10,250±0,008	8,13	-0,833±0,008	-0,765±0,007	-0,0200±0,0006
					100	-0,877±0,008	10,789±0,008	8,13	-0,877±0,008	-0,806±0,007	-0,0200±0,0006
					60	-0,547±0,005	6,453±0,005	8,48	-0,547±0,005	-0,501±0,005	-0,0200±0,0006
					65	-0,592±0,006	6,990±0,006	8,47	-0,592±0,006	-0,542±0,006	-0,0200±0,0006
					70	-0,638±0,006	7,528±0,006	8,48	-0,638±0,006	-0,584±0,006	-0,0200±0,0006
					75	-0,684±0,006	8,066±0,006	8,48	-0,684±0,006	-0,626±0,006	-0,0200±0,0006
					80	-0,729±0,007	8,604±0,007	8,47	-0,729±0,007	-0,667±0,007	-0,0200±0,0006
53	135	83	52±0,5	0,547±0,005	85	-0,775±0,007	9,141±0,007	8,48	-0,775±0,007	-0,709±0,007	-0,0200±0,0006
					90	-0,821±0,008	9,679±0,008	8,48	-0,821±0,008	-0,751±0,007	-0,0200±0,0006
					95	-0,866±0,008	10,217±0,008	8,48	-0,866±0,008	-0,793±0,007	-0,0200±0,0006
					100	-0,912±0,009	10,754±0,009	8,48	-0,912±0,009	-0,835±0,008	-0,0200±0,0006
					60	-0,536±0,005	6,463±0,005	8,29	-0,536±0,005	-0,492±0,008	-0,0200±0,0006
					65	-0,581±0,006	7,002±0,006	8,29	-0,581±0,006	-0,533±0,006	-0,0200±0,0006
					70	-0,626±0,006	7,540±0,006	8,30	-0,626±0,006	-0,574±0,006	-0,0200±0,0006
					75	-0,671±0,006	8,079±0,006	8,30	-0,671±0,006	-0,615±0,006	-0,0200±0,0006
					80	-0,715±0,007	8,618±0,007	8,30	-0,715±0,007	-0,656±0,007	-0,0200±0,0006
63	138	87	51±0,5	0,536±0,005	85	-0,760±0,007	9,156±0,007	8,30	-0,760±0,007	-0,697±0,007	-0,0200±0,0006
					90	-0,805±0,008	9,695±0,008	8,30	-0,805±0,008	-0,738±0,007	-0,0200±0,0006
					95	-0,850±0,008	10,233±0,008	8,30	-0,850±0,008	-0,779±0,007	-0,0200±0,0006
					100	-0,894±0,009	10,772±0,009	8,30	-0,894±0,009	-0,820±0,007	-0,0200±0,0006
					60	-0,536±0,005	6,463±0,005	8,29	-0,536±0,005	-0,492±0,005	-0,0200±0,0006
					65	-0,581±0,006	7,002±0,006	8,29	-0,581±0,006	-0,533±0,006	-0,0200±0,0006
					70	-0,626±0,006	7,540±0,006	8,30	-0,626±0,006	-0,574±0,006	-0,0200±0,0006
					75	-0,671±0,006	8,079±0,006	8,30	-0,671±0,006	-0,615±0,006	-0,0200±0,0006
					80	-0,715±0,007	8,618±0,007	8,30	-0,715±0,007	-0,656±0,007	-0,0200±0,0006
73	140	89	51±0,5	0,536±0,005	85	-0,760±0,007	9,156±0,007	8,30	-0,760±0,007	-0,697±0,007	-0,0200±0,0006
					90	-0,805±0,008	9,695±0,008	8,30	-0,805±0,008	-0,738±0,007	-0,0200±0,0006
					95	-0,850±0,008	10,233±0,008	8,30	-0,850±0,008	-0,779±0,007	-0,0200±0,0006
					100	-0,894±0,009	10,772±0,009	8,30	-0,894±0,009	-0,820±0,008	-0,0200±0,0006

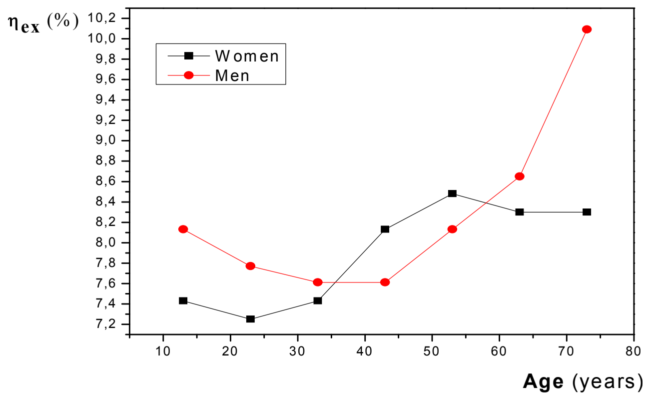


Fig.1. Cardiac yield versus age

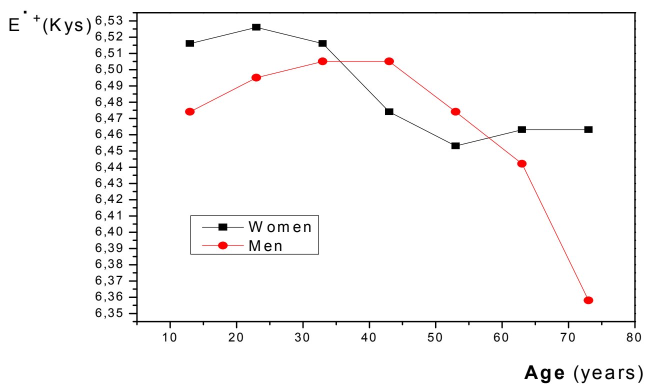


Fig.2a. E^+ versus age at f_C = 60 bpm

Table 2.Thermoexergetic parameters for healthy men (13-73 years old)

Age (years)	P_s (mmHg)	P_d (mmHg)	$P_D \pm P_D$ (mmHg)	$H_D \pm H_D$ (J)	f_c (bpm)	$P_c \pm P_c$ (W)	$E^+ \pm E^+$ (Kys)	η_{ex} (%)	$E_e^+ \pm E_e^+$ (W)	$L \pm L$ (W)	s ($J\ kg^{-1}K^{-1}$)
					60	-0,526±0,005	6,474±0,005	8,13	-0,526±0,005	-0,483±0,005	-0,0200±0,0006
					65	-0,570±0,005	7,013±0,005	8,13	-0,570±0,006	-0,525±0,005	-0,0200±0,0006
					70	-0,614±0,006	7,553±0,006	8,13	-0,614±0,006	-0,564±0,006	-0,0200±0,0006
13	118	68	50±0,5	0,526±0,005	75	-0,657±0,006	8,092±0,006	8,12	-0,657±0,006	-0,604±0,006	-0,0200±0,0006
					80	-0,701±0,007	8,632±0,007	8,12	-0,701±0,007	-0,644±0,007	-0,0200±0,0006
					85	-0,745±0,007	9,171±0,007	8,12	-0,745±0,007	-0,685±0,007	-0,0200±0,0006
					90	-0,789±0,008	9,711±0,008	8,12	-0,789±0,008	-0,725±0,007	-0,0200±0,0006
					95	-0,833±0,008	10,250±0,008	8,13	-0,833±0,008	-0,765±0,007	-0,0200±0,0006
					100	-0,877±0,008	10,789±0,008	8,13	-0,877±0,008	-0,806±0,007	-0,0200±0,0006
					60	-0,505±0,005	6,495±0,005	7,77	-0,505±0,005	-0,466±0,005	-0,0200±0,0006
					65	-0,547±0,005	7,036±0,005	7,77	-0,547±0,005	-0,504±0,005	-0,0200±0,0006
					70	-0,589±0,006	7,577±0,006	7,77	-0,589±0,006	-0,543±0,006	-0,0200±0,0006
					75	-0,631±0,006	8,118±0,006	7,77	-0,631±0,006	-0,582±0,006	-0,0200±0,0006
					80	-0,673±0,007	8,660±0,007	7,77	-0,673±0,007	-0,621±0,007	-0,0200±0,0006
23	123	75	48±0,5	0,505±0,005	85	-0,715±0,007	9,201±0,007	7,77	-0,715±0,007	-0,659±0,007	-0,0200±0,0006
					90	-0,757±0,008	9,742±0,008	7,77	-0,757±0,008	-0,689±0,008	-0,0200±0,0006
					95	-0,800±0,008	10,283±0,008	7,77	-0,800±0,008	-0,738±0,008	-0,0200±0,0006
					100	-0,842±0,008	10,825±0,008	7,77	-0,842±0,008	-0,777±0,008	-0,0200±0,0006
					60	-0,495±0,005	6,505±0,005	7,61	-0,495±0,005	-0,457±0,005	-0,0200±0,0006
					65	-0,536±0,005	7,047±0,005	7,61	-0,536±0,005	-0,495±0,005	-0,0200±0,0006
					70	-0,577±0,006	7,589±0,006	7,60	-0,577±0,006	-0,533±0,006	-0,0200±0,0006
					75	-0,618±0,006	8,132±0,006	7,60	-0,618±0,006	-0,571±0,006	-0,0200±0,0006
					80	-0,660±0,007	8,674±0,007	7,61	-0,660±0,007	-0,610±0,007	-0,0200±0,0006
33	120	73	47±0,5	0,495±0,005	85	-0,701±0,007	9,216±0,007	7,61	-0,701±0,007	-0,648±0,007	-0,0200±0,0006
					90	-0,742±0,008	9,758±0,008	7,60	-0,742±0,008	-0,686±0,008	-0,0200±0,0006
					95	-0,783±0,008	10,300±0,008	7,60	-0,783±0,008	-0,723±0,008	-0,0200±0,0006
					100	-0,825±0,008	10,842±0,008	7,61	-0,825±0,008	-0,762±0,008	-0,0200±0,0006
					60	-0,495±0,005	6,505±0,005	7,61	-0,495±0,005	-0,457±0,005	-0,0200±0,0006
					65	-0,536±0,005	7,047±0,005	7,61	-0,536±0,005	-0,495±0,005	-0,0200±0,0006
					70	-0,577±0,006	7,589±0,006	7,60	-0,577±0,006	-0,533±0,005	-0,0200±0,0006
43	131	81	50±0,5	0,526±0,005	75	-0,618±0,006	8,132±0,006	7,60	-0,618±0,006	-0,571±0,006	-0,0200±0,0006
					80	-0,660±0,007	8,674±0,007	7,61	-0,660±0,007	-0,610±0,007	-0,0200±0,0006
					85	-0,701±0,007	9,216±0,007	7,61	-0,701±0,007	-0,648±0,007	-0,0200±0,0006
					90	-0,742±0,008	9,758±0,008	7,60	-0,742±0,008	-0,686±0,008	-0,0200±0,0006
					95	-0,783±0,008	10,300± 0,008	7,60	-0,783±0,008	-0,723±0,008	-0,0200±0,0006
					100	-0,825±0,008	10,842±0,008	7,61	-0,825±0,008	-0,762±0,008	-0,0200±0,0006
					60	-0,526±0,005	6,474±0,005	8,13	-0,526±0,005	-0,483±0,005	-0,0200±0,0006
					65	-0,570±0,005	7,013±0,005	8,13	-0,570±0,005	-0,525±0,005	-0,0200±0,0006
					70	-0,614±0,006	7,553±0,006	8,13	-0,614±0,006	-0,564±0,006	-0,0200±0,0006
					75	-0,657±0,006	8,092±0,006	8,12	-0,657±0,006	-0,604±0,006	-0,0200±0,0006
					80	-0,701±0,007	8,632±0,007	8,12	-0,701±0,007	-0,644±0,007	-0,0200±0,0006
53	135	82	50±0,5	0,526±0,005	85	-0,745±0,007	9,171±0,007	8,12	-0,745±0,007	-0,685±0,007	-0,0200±0,0006
					90	-0,789±0,008	9,711±0,008	8,12	-0,789±0,008	-0,725±0,007	-0,0200±0,0006
					95	-0,833±0,008	10,250±0,008	8,13	-0,833±0,008	-0,765±0,007	-0,0200±0,0006
					100	-0,877±0,008	10,789±0,008	8,13	-0,877±0,008	-0,806±0,007	-0,0200±0,0006
					60	-0,557±0,005	6,442±0,005	8,65	-0,557±0,005	-0,509±0,005	-0,0200±0,0006
					65	-0,604±0,005	6,979±0,006	8,65	-0,604±0,005	-0,552±0,006	-0,0200±0,0006
					70	-0,650±0,006	7,516±0,006	8,65	-0,650±0,006	-0,594±0,006	-0,0200±0,0006
					75	-0,697±0,006	8,053±0,006	8,65	-0,697±0,006	-0,637±0,006	-0,0200±0,0006
					80	-0,743±0,007	8,589±0,007	8,65	-0,743±0,007	-0,679±0,007	-0,0200±0,0006
63	140	82	53±0,5	0,557±0,005	85	-0,790±0,007	9,126±0,007	8,65	-0,790±0,007	-0,722±0,007	-0,0200±0,0006
					90	-0,836±0,008	9,663±0,008	8,65	-0,836±0,008	-0,764±0,007	-0,0200±0,0006
					95	-0,883±0,008	10,20±0,008	8,65	-0,883±0,008	-0,807±0,007	-0,0200±0,0006
					100	-0,929±0,008	10,737±0,008	8,65	-0,929±0,008	-0,849±0,007	-0,0200±0,0006
					60	-0,642±0,005	6,358±0,005	10,09	-0,642±0,005	-0,577±0,005	-0,0200±0,0006
					65	-0,695±0,005	6,888±0,005	10,09	-0,695±0,005	-0,625±0,005	-0,0200±0,0006
					70	-0,749±0,006	7,418±0,006	10,09	-0,749±0,006	-0,673±0,006	-0,0200±0,0006
					75	-0,802±0,006	7,947±0,006	10,09	-0,802±0,006	-0,721±0,006	-0,0200±0,0006
					80	-0,856±0,007	8,447±0,007	10,09	-0,856±0,007	-0,769±0,007	-0,0200±0,0006
73	142	81	61±0,5	0,642±0,005	85	-0,909±0,007	9,007±0,007	10,09	-0,909±0,007	-0,817±0,006	-0,0200±0,0006
					90	-0,963±0,008	9,537±0,008	10,09	-0,963±0,008	-0,866±0,007	-0,0200±0,0006
					95	-1,016±0,008	10,067±0,008	10,09	-1,016±0,008	-0,913±0,007	-0,0200±0,0006
					100	-1,070±0,009	10,596±0,009	10,09	-1,070±0,009	-0,962±0,008	-0,0200±0,0006

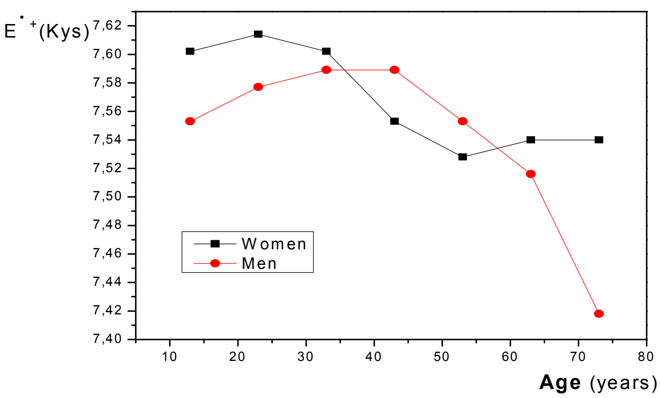


Fig. 2b. E^+versus age at f_C = 70 bpm

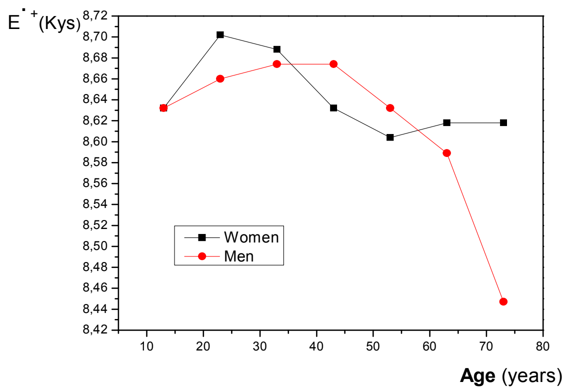


Fig.2c. E^+ versus age at f_C = 80 bpm

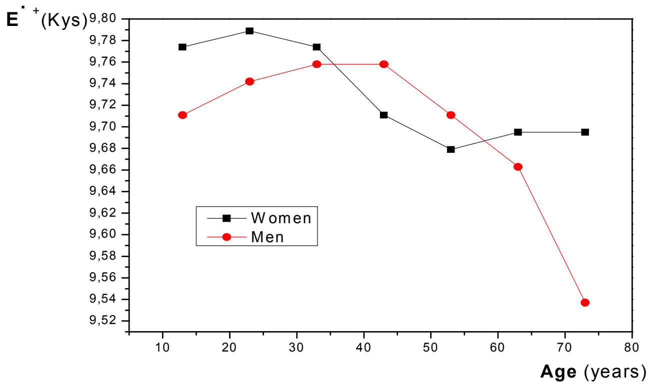
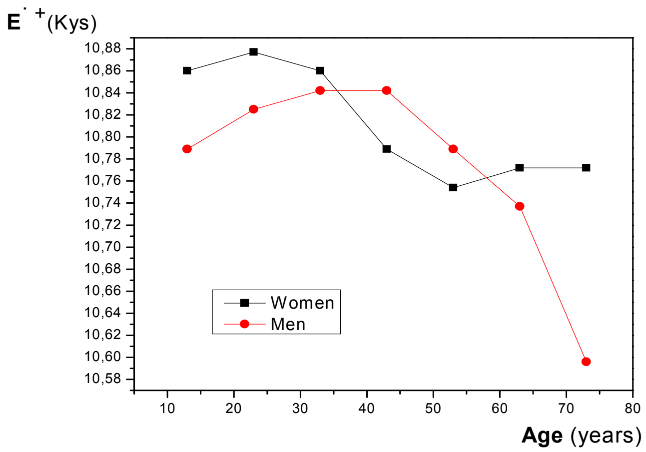
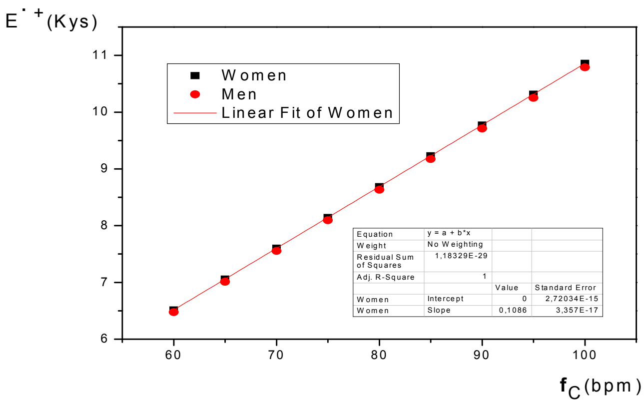


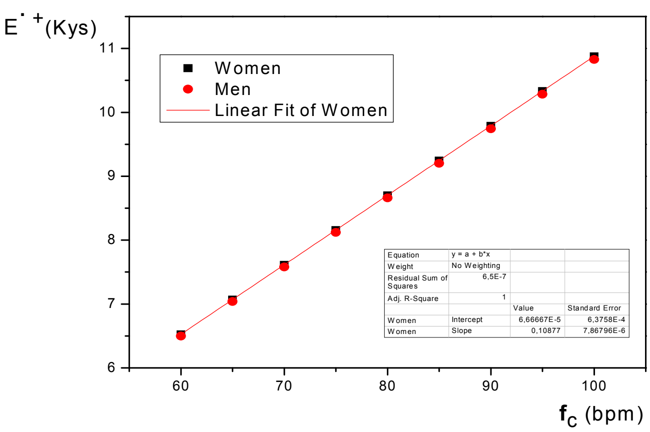
Fig. 2d. E^{+}versus age at $f_C = 90$ bpm



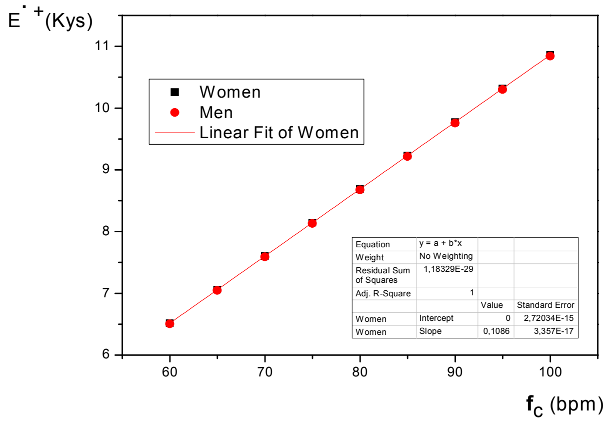
$Fig.2e.E^{+}versus\ age\ at\ f_C\ =\ 100\ bpm$



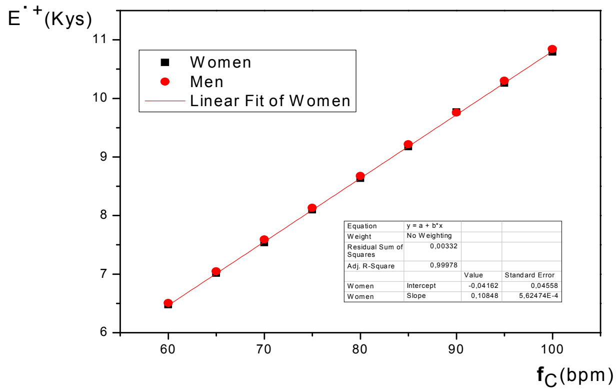
$Fig.3a.\ E^{+}versusf_C\ at\ 13\ years\ old$



$Fig.3b.\ E^{+}versusf_C\ at\ 23\ years\ old$



$Fig.3c.E^{+}versusf_C\ at\ 33\ years\ old$



$Fig.3d.E^{+}versusf_C\ at\ 4\ 3years\ old$

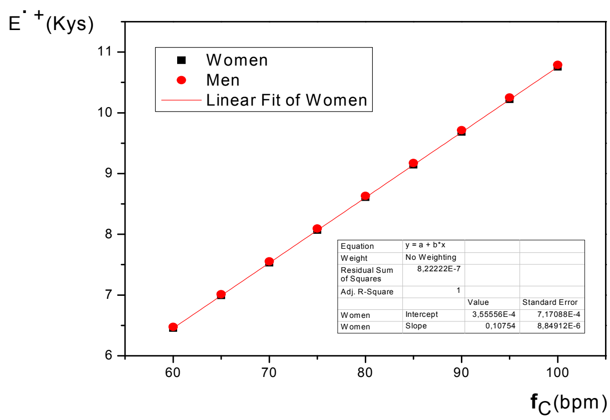


Fig. 3e. E^{+}versusf_C at 53 years old

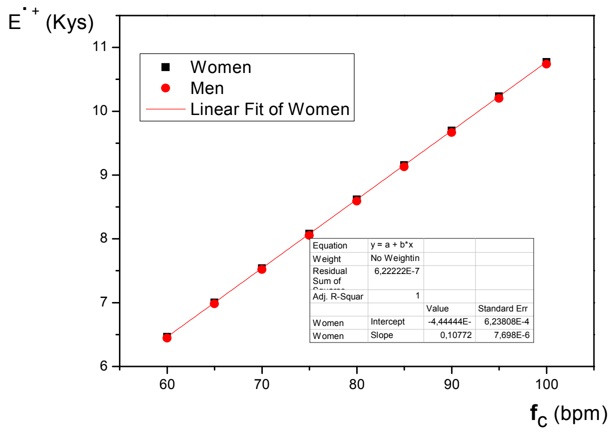


Fig. 3f. E^{+}versusf_C at 63 years old

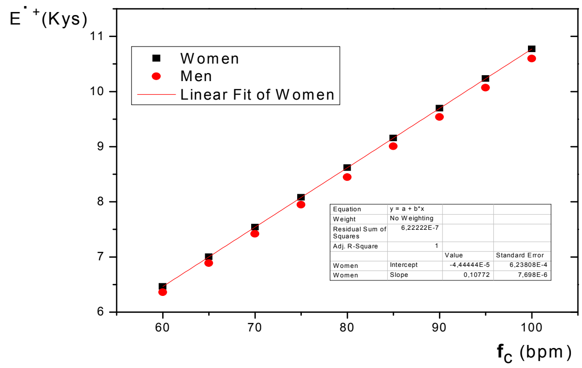


Fig. 3g. E^{+}versusf_C at 73 years old

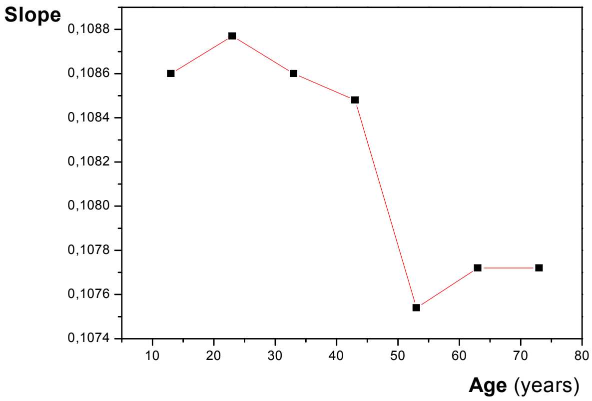


Fig. 3h. Slopes of E^{+} versus f_C versus age

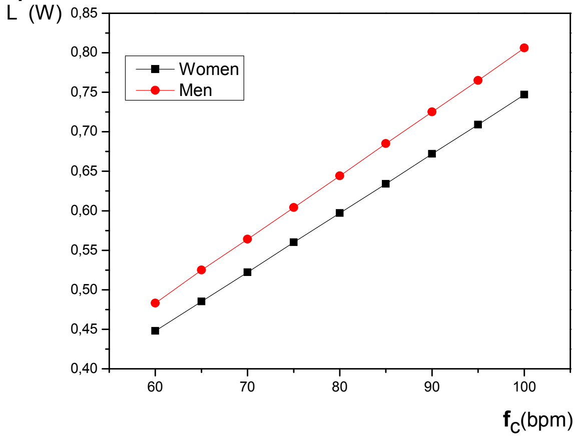


Fig. 4a. Lversusf_C at 13 years old

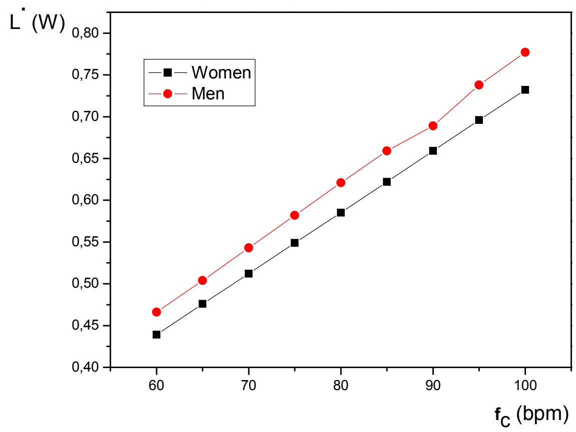


Fig. 4b. Lversusf_C at 23 years old

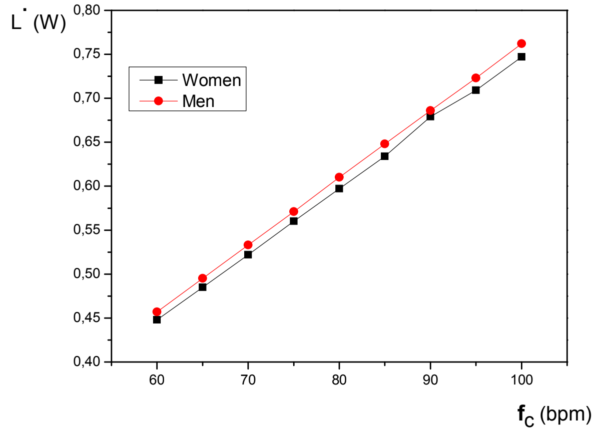


Fig. 4c. Lversusf_C at 33 years old

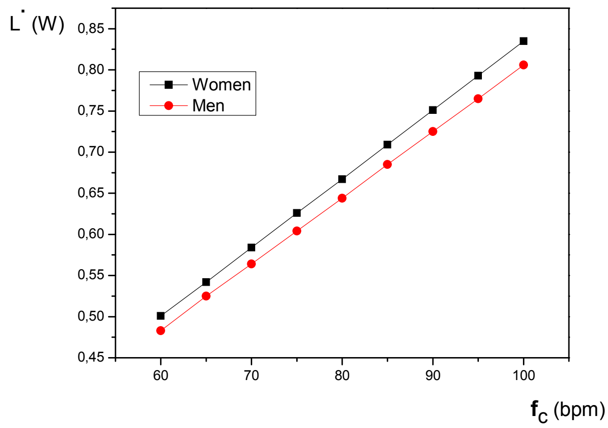


Fig. 4d. Lversusf_C at 43 years old

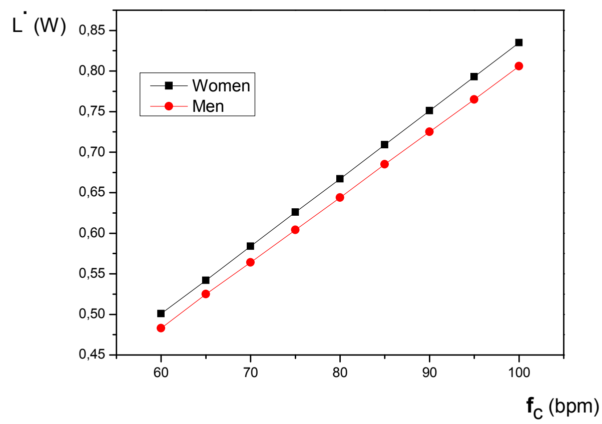


Fig. 4e. Lversusf_C at 53 years old

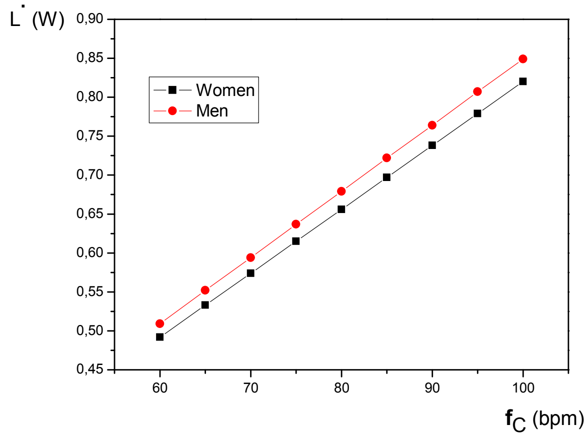


Fig. 4f. Lversusf_C at 63 years old

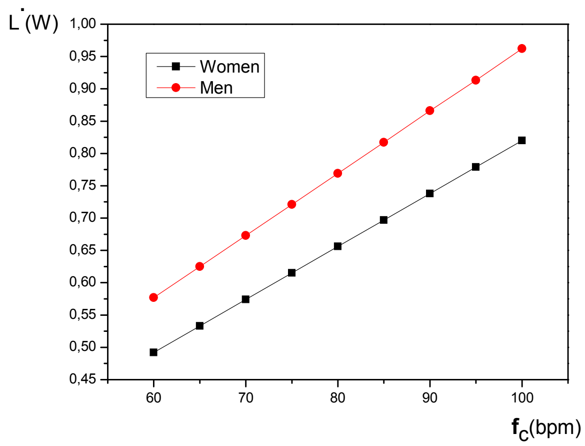


Fig. 4g. *L*versusf_C at 63 years old

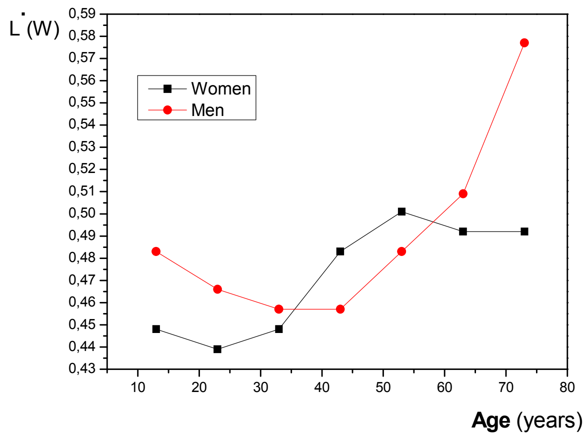


Fig. 5a. *L*versus Age at f_C = 60

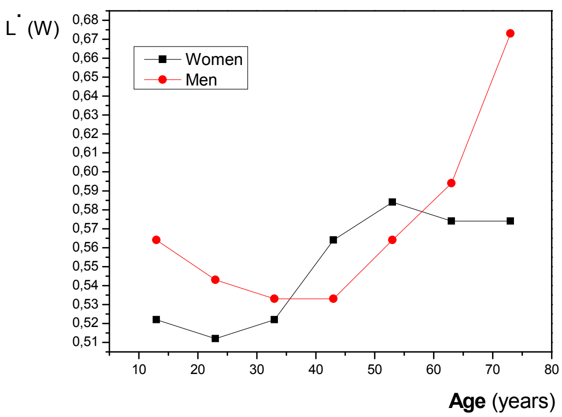


Fig. 5b. *L*versus Age f_C = 70

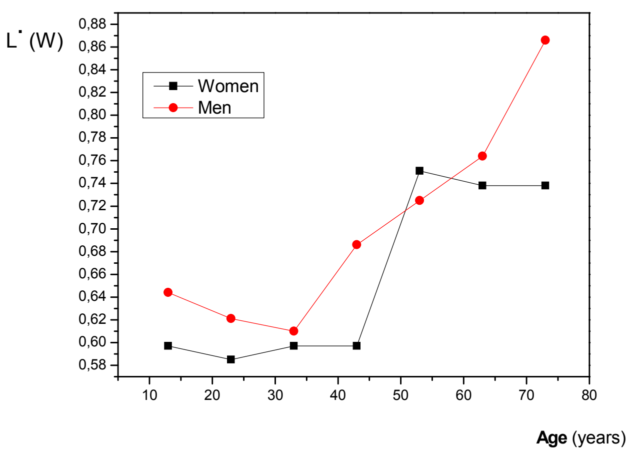


Fig. 5c. *L*versus Age at f_C= 80

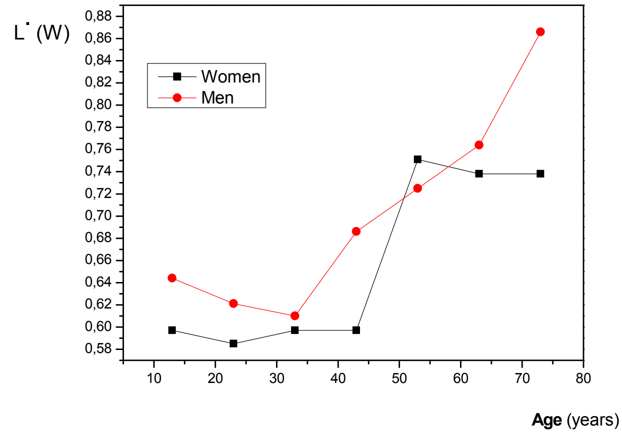


Fig. 5d. *L*versus Age at f_C= 90

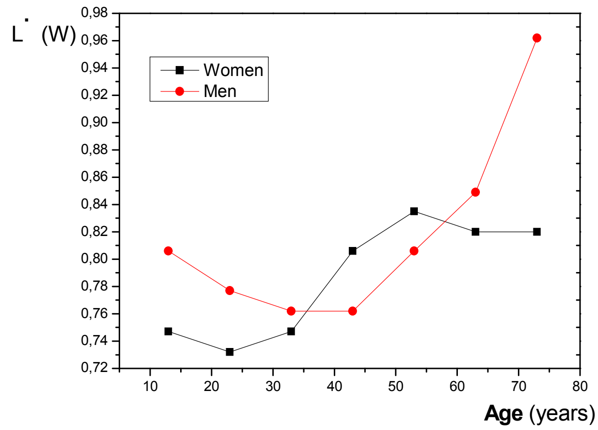


Fig. 5e. *L*versus Age at f_C= 100

Table 3. Slopes as function of age

Age (years)	Slopes
13	0,10860
23	0,10877 (max)
33	0,10860
43	0,10848
53	0,10754(min)
63	0,10772
73	0,10772

When those intervals of E^+ are analyzed, it can be concluded that at a given cardiac frequency the work power (E^+) remains slightly different through the ages and through the sexes. It depend more on cardiac frequency than on age as it is shown in figure 3. The observation of these figures shows the presence of straight lines for E^+versus f_C where it can be seen the total superposition of straight lines for men and women giving one slope even though there is very small difference at each cardiac frequency, difference due to the age. The slopes, giving the variation of E^+ versus f_C and representing the corresponding energy of the influx received by the system, have been calculated and found constant at a given age. Note that this energy is the same for two sexes at a given age. The fig.3h, corresponding to the table 3, shows the variation of the slopes of E^+ versus f_C versus age. It can be seen in this above-mentioned figure two characteristic ages. The energy is maximum at 23 years old and minimum at 53 years old. Research is continuing in laboratory in order to elucidate all those aspects, for example why in such a cross section of life there is minimum of energy and in such another there is a maximum. At the onset the response should be searched in cellular metabolism. The slopes have been found by fitting, using the origin 8 program. The analysis of the exergetic losses in power shows their increase as a function of the cardiac frequencies in each cross section of life as well for men as for women (figure 4). The observation of women and men straight lines shows their inversion at 43 and 53 years old where the women lines are over meaning that the inversion can occur. At as given cardiac frequency, L changes with the age as well for men as for women (figure 5) and it can be seen that L men is somewhat high except some inversions observed. Concerning the entropy variation, it is constant, small and negative. That means the state (1) of the chosen thermodynamic system is a little bit more disturbed than the state (2). The entropy variation depends neither on cardiac frequency nor on age. It has been indeed reported that the variation of entropy is negative for an irreversible system.

Conclusion

Man heart with its great mass, has generally the exergetic parameters somewhat high compared to woman heart. Exception can occur at certain cross section of life. The heart exergetic yield, also called cardiac yield, is a measure of its performance and its longevity. A healthy heart should have a weak cardiac yield since it works contineously tens of years without stopping (Cherruault Y. Biomathématiques, 1983; Bénazeth *et al.,* 2004; Fliers *et al.,* 2003; Kunyima *et al.,* 2016). The importance of E^{+} knowledge should be underlined. It will be needful in near future to engrave the cardiac yield in apparatus memory because this parameter better describes the heart acting.

Abbreviations

KUNYIMA units (Ky→pl. Kys); Variation of the total differential enthalpy(H_D*); Cardiac frequency (*f_c*);Cardiac power (*P_C*); Differential pressure (*P_D*);* massic entropy variation [s]; exergetic yield [η_{ex}]; exergetic loss *[L];* effective work power [E_e^{+}]; work power [E^{+}].

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