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Cardiovascular Reflex in Response to Supine and Upright Exercise

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الخلاصة:

أُجرت هذ الدراسة على (٢١) شخصاً من الأصحاء المتطوع ن من الذكور الذ ن تتراوح أعمارهم ب ن ٢٠-٤٠ سنة لأجل دراسة إنعكاسات القلب والأوع ة الدمو ة إستجابة لتغ ر وضع جسم الإنسان (الأفقي الإستلقاء على الظهر والعمودي القائم) في حالة الراحة أو السكون، وخلال التمر ن، وتم إجراء الدراسة باستخدام الدراجة الهوائ ة الطب ة (Bicycle ergometer) لغرض إجراء التمر ن وجهاز الضغط الزئبقي لأجل ق اس ضغط الدم، وجهاز الإ كو الدوبلر (Doppler Echocardiography) لق اس نبضات القلب (HR)، كم ة الدم التي ضخها القلب خلال نبضة واحدة (SV)، كم ة الدم التي ضخها القلب في الدق قة الواحدة (CO)، سرعة الوقت المتكاملة (VTI)، وقت قذف الدم من البط ن الأ سر(ET)، سرعة الجر ان القصوى للدم خلال الصمام الأبهر(Vmx) ودرجة التحدر القصوى للضغط عبرالصمام الأبهر(PGmx).

تب ن من التحل ل الإحصائي أنه خلال حالة الراحة أو السكون هناك ز ادة معنو ة في نبضات القلب، ضغط الدم الواطئ، متوسط ضغط الدم، المقاومة المح ط ة للأوع ة الدمو ة. وهنالك نقصان معنوي في كم ة الدم التي ضخها القلب في النبضة الواحدة وفي الدق قة الواحدة، سرعة الوقت المتاكاملة، وقت قذف الدم من البط ن الأ سر في حالة الوضع القائم مقارنة بالوضع الأفقي (الإستلقاء على الظهر)، لكنه لا وجد فرق معنوي في ضغط الدم العالي، سرعة الجر ان القصوى للدم خلال الصمام الأبهر، ودرجة التحدر القصوى للضغط عبر الصمام الأبهر.

في حالة التغ ر من السكون إلى التمر ن وجد أنّ جم ع المتغ رات المذكورة أعلا تتغ ر بصورة معنو ة، وفي كلتا الوضع ت ن للجسم (الإستلقاء على الظهر والقائم)، باستثناء وقت قذف الدم من البط ن الأ سر في الوضع العمودي، ح ث أنه لا وجد فرق معنوي بالرغم من النقصان الحاصل بصورة قل لة.

وعند المقارنة بين التمرين في حالة الوضع الأفقي (الإستلقاء على الظهر)، وبين التمرين في حالة الوضع القائم، وجد أنَّ هنالك زيادة معنوية في نبضات القلب، ضغط الدم العالي، المقاومة المحيطية ونقصان معنوي في كمية الدم التي يضخها القلب في النبضة الواحدة، وفي الدقيقة الواحدة، سرعة الوقت المتكاملة في حالة التمرين في الوضع القائم، مقارنة بالتمرين في الوضع الأفقي.

وعند المقارنة بين الفروقات في الوضع الأفقي والفروقات في الوضع القائم إستجابة للتمرين، وجد أنَّ هنالك زيادة معنوية في نبضات القلب، ضغط الدم العالي، المقاومة المحيطية، ونقصان معنوي قي كمية الدم التي يضخها القلب في الدقيقة الواحدة، ضغط الدم الواطئ، وقت قذف الدم من البطين الأيسر في الوضع القائم، مقارنة بالوضع الأفقي. بينما لا يوجد فرق معنوي في المتغيرات الأخرى.

من خلال هذه الدراسة تبين أنَّ هنالك علاقة عكسية بين نبضات القلب ووقت قذف الدم من البطين الأيسر، وعلاقة طردية بين سرعة الوقت المتكاملة وسرعة جريان الدم القصوى خلال الصمام الأبهر.

Abstract:

This study was carried out on 21 normal healthy male volunteers, aged 20-40 years in order to study cardiovascular reflexes response to postural changes at rest and during exercise by using non-invasive technique. Bicycle ergo-meter for doing exercise, mercury sphygmomanometer for measuring the blood pressure(BP) and Doppler echocardiography for estimating of heart rate(HR), stroke volume(SV), cardiac output(CO), velocity time integral(VTI), ejection time(ET), peak or maximum flow velocity through aortic valve(Vmx) and maximum pressure gradient across aortic valve(PGmx). The results were at rest there are significant increase in HR, diastolic BP, mean BP, peripheral vascular resistance(PVR) and significant decrease in SV, CO, VTI, ET in upright position on comparison with the supine position, while systolic BP, Vmx, PGmx are not significantly different between both positions at rest.

During change from rest to exercise all variables significantly changed in both positions except ET during upright exercise which is not significantly decreased.

On comparison between supine and upright exercise it was found that there are significantly higher HR, systolic BP, PVR and significantly lower SV, CO, VTI in

upright exercise in comparison with supine exercise, while diastolic BP, mean BP, ET, Vmx, PGmx are not significantly different between supine and upright exercise.

On comparison between the differences in both positions in response to exercise it was found that there are significantly higher HR, systolic BP, PVR and significantly lower CO, diastolic BP, ET in upright position on comparison with the supine position, while mean BP, VTI, Vmx, PGmx not significantly changed.

We concluded that there is inverse relationship between HR and ET and direct relationship between VTI and Vmx.

Introduction:

There have been many researches for assessment of the cardiovascular reflex. responses to exercise(1,2) responses to supine exercise(3,4) and to upright exercise on bicycle ergometer(5,6) or on treadmill exercise(7,8) but only very few researches about the comparison between responses to supine and upright exercise on bicycle ergometer.(9,10,11) Morever there are many controversy in results of these studies, it was reported that the responses of cardiac out put (CO) and stroke volume (SV) to supine and upright exercise was the same(4,12), stroke volume (SV) more in supine exercise than upright exercise(4) other reported that there was no change inresponses of (SV) to supine exercise compared to control value, but increase only in responses of systolic blood pressure (SBP) was the same in supine and upright exercise(4,9) more in upright exercise.(8)

The diastoric blood pressure (DBP) increased more in upright exercise than supine exercise.(4,9,14) The mean blood pressure (MBP) increased more in supine exercise than the upright exercise.(10) Other investigators reported that (MBP) increased more in upright exercise than that in supine exercise. (9,14)

The peripheral vascular resistance (PVR) usually decreased in upright exercise compared to control value.(11)

The value of maximum flow velocity through aortic value (vmx) was significantly increase in supine exercise(3) significantly increase in upright exercise (double value).(15)

The velocity time integral (CTI) significantly decrease at supine exercise and ejection time (ET) significantly decrease of supine exercise and significantly decrease at supright exercise.(15)

Method and Materials:

This study was carried out on 21 normal healthy male volunteers. All subjects are normal, with no symptoms or signs of any disease.

The details of anthropometric data are presented in table 1.

Table (1): Anthropometric data.

Anthropometric Data	Group Data(n=21)
Age range(years)	**20-40years**
Mean age±SD(years)	**29.3±6.85**
Mean weight±SD(Kg)	**69.3±6.89**
Mean height±SD(cm)	**171.3±4.5**
Body surface area(BSA) ±SD(m^2)	**1.8±0.1**
Body mass index(BMI) ±SD(Kg/m^2)	**22.6±2.3**

The instrument used in our study is a bicycle ergo meter of tunturi model (E 315) which consists of assembly and meter. The assembly content includes frame(A), rear support(B), handlebar support tube(C), plastic covers for front support(D), resistance adjustment knob(H), pedals(E) and ear sensor for pulse measurement(F) as shown in (Figure 8a). The meter allows the users to monitor the effort level during the workout and the SCAN-function enables them to view all displays automatically (Figure 8b).

The study was performed by using Siemens versa plus Sonoline equipment with 2-4MHz transducer made in Germany. Transthoracic 2-D guided M-mode and Doppler echocardiography guidelines (Sahn *et al.*, 1978).

The sphygmomanometer is the standard and most widely used non-invasive method for recording arterial BP in clinical practice (Tein *et al.*, 1982). The ascultatory method is the most popular method for BP measurement today(Simpson and Wicks, 1988) by using phase one of Korotkoff sound to point out the SBP and phase five for DBP reading (Hoffler and Robert, 2001).

Full clinical history and anthropometric data were taken prior to the test.

It consists of four phases:

Phase-1 (supine rest): The subjects first placed in supine position with the feet on the pedals of a flywheel bicycle ergo meter then measurement of blood pressure and heart rate were made after a steady state (steady state: means that the heart rate into two consecutive minutes changing by less than 3 beat/min) (Al-Shamma and Al-Zubaidy, 1999).

Phase-2 (supine exercise): This phase begins when the subjects start supine bicycle exercise which continues for 3 minutes. The bicycle is mounted on the examination table at work load.

Phase-3 (upright rest): The subjects resting in upright position (seated on bicycle ergo meter saddle) till recover to the steady state.

Phase-4 (upright exercise): It was performed by using bicycle ergo meter in which exercise last for 3 minutes at the same work load.

Supine and upright exercises (phase 2 and 4) performed by using bicycle ergo meter (Tunturi E315) in a single-level exercise testing at 120 watts lasting 3 minutes and with the constant resistance .Care was taken to perform exercises at relatively the same HR or to get relatively the same HR.

In all four phases the blood pressure (SBP and DBP) is measured by standard cuff sphygmomanometer.

The mean arterial BP (MBP) is calculated as DBP plus one third of pulse pressure (difference between SBP and DBP) (Rushmer, 1976; Nixon *et al*., 1982).

The Doppler echocardiography is used to calculate heart rate (HR), stroke volume (SV), velocity time integral (VTI), ejection time (ET), peak flow velocity across the aortic valve (Vmx), maximum pressure gradient across the aortic valve (PGmx). The angle of insonation is set at 0 degree in Doppler study.

The M-mode is utilized to measure aortic valve diameter during systole.

The crosses sectional area of the aorta was calculated at rest with the subject in supine position by measuring the diameter of aortic root at the annulus with M-mode echocardiography guided by cross sectional echocardiography. The area (A) of the aorta at the annulus calculated as $A=3.14 \times (D/2)^2$ -------$A=0.785 \times D^2$ (Crawford *et al*., 1979; Patrick *et al*., 1985; Rowland *et al*., 2001; Akeel Zwain, 2007).

VTI was determined by integrating the peak velocity curves (from systolic flow in the ascending aorta) over time. Peak velocity curves were integrated by computer by digitizing hardcopy data (Patrick *et al*., 1985; Akeel Zwain, 2007).So we use the following equations:

$$SV=0.785 \times D^2 \times VTI$$

CO= SV X HR

Ejection time was measured from the onset of systolic flow until end systole as determined by the time at which the curve crossed the zero flow line (Patrick *et al*., 1985). The peripheral vascular resistance (PVR) calculated according to the equation PVR= MBP/CO.

Data analysis was performed on the results obtained from males group presented as mean±Standard deviation (SD) for all variables (haemodynamic and other variables) as well compared by using the paired t test and simple Student t test to determine: (a) If there are differences in the differences of cardiovascular reflexes between supine and upright positions at the rest and during exercise. (b) If there are differences in the cardiovascular reflexes between supine and upright positions at the rest.

(c) If there are differences in the cardiovascular reflexes between supine and upright positions during exercise.

The differences were considered significant if $P<0.05$, all calculation, tables and graphs performed by Microsoft SPSS and Excel computerized program (Lwange *et al*., 1999).

Results:

1- Cardiovascular reflex responses to exercise in the supine and upright positions:

In supine position, cardiovascular reflex responses to exercise in comparison with the rest condition indicating that there are significant changes in all variables i.e significantly increased in HR, SV, CO, SBP, MBP, VTI, Vmx and PGmx; and significantly decreased in DBP, PVR and ET.

In upright position, cardiovascular reflex responses to exercise in comparison with the rest condition indicating that there are significant changes in all variables except ET. There is significant increase in HR, SV, CO, SBP, MBP, VTI, Vmx and PGmx but significant decrease in DBP and PVR and no significant changes (slightly decreased) in ET.

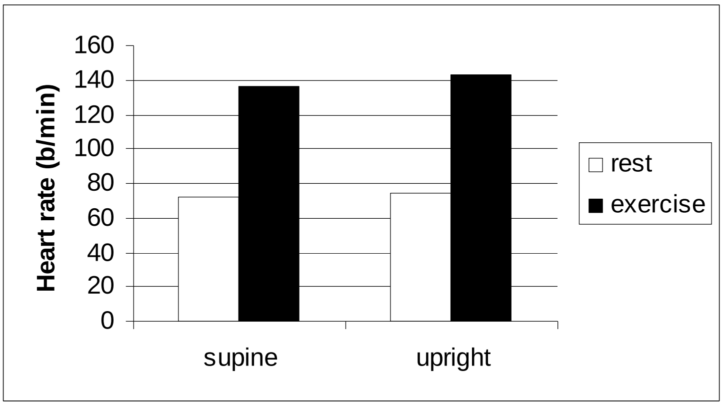

Figure (1): Heart rate in supine and upright positions at rest and during exercise.

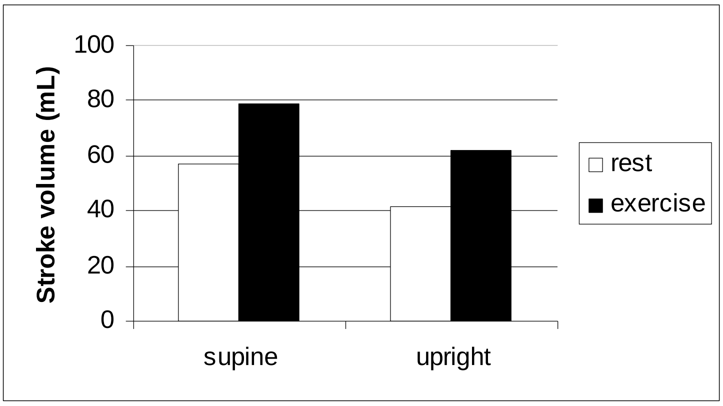

Figure (2): Stroke volume in supine and upright positions at rest and during exercise.

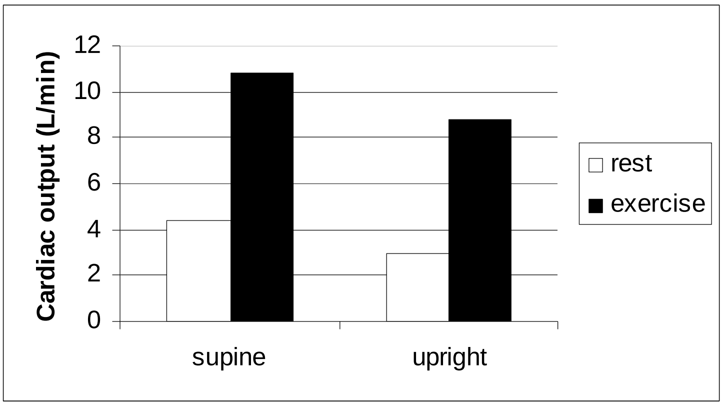

Figure (3): Cardiac output in supine and upright positions at rest and during exercise.

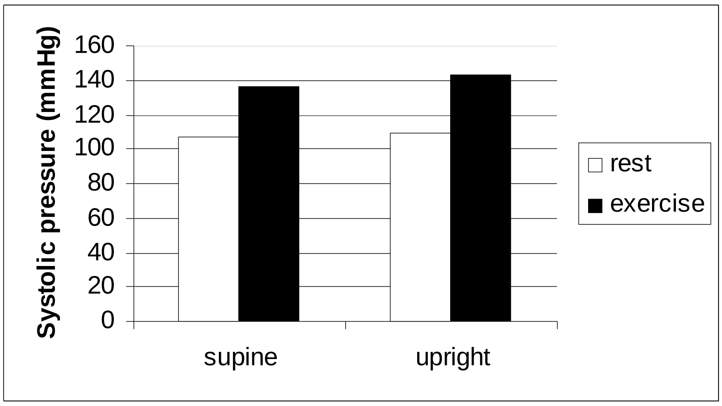

Figure (4): Systolic blood pressure in supine and upright positions at rest and during exercise.

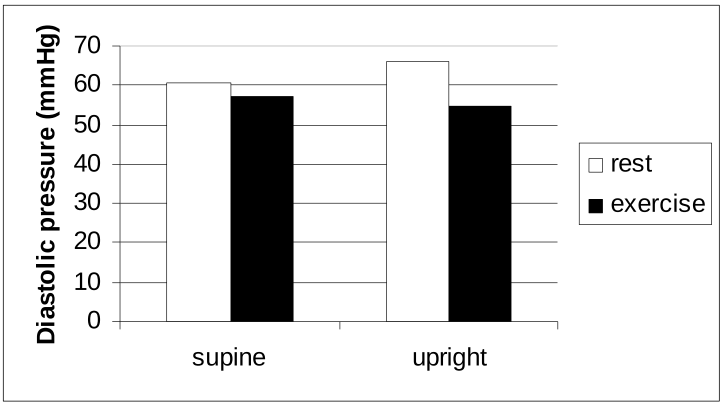

Figure (5): Diastolic blood pressure in supine and upright positions at rest and during exercise.

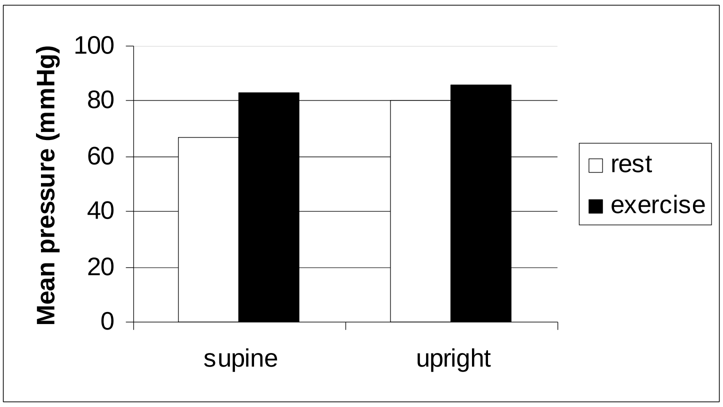

Figure (6): Mean blood pressure in supine and upright positions at rest and during exercise.

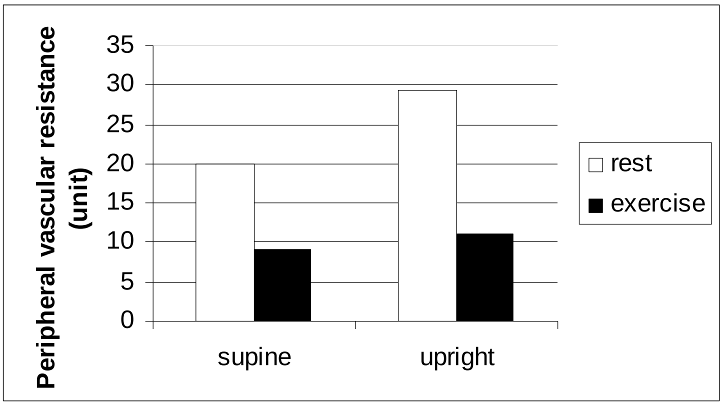

Figure (7): Peripheral vascular resistance in supine and upright positions at rest and during exercise.

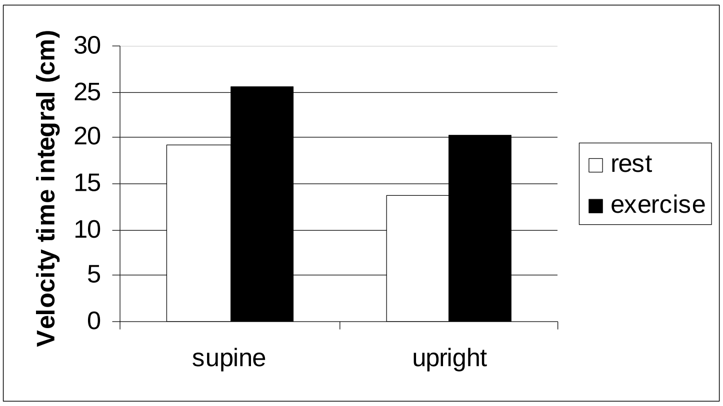

Figure (8): Velocity time integral in supine and upright positions at rest and during exercise.

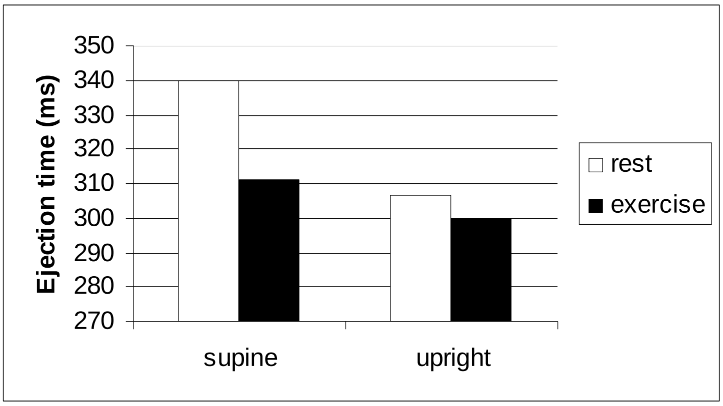

Figure (9): Ejection time in supine and upright positions at rest and during exercise.

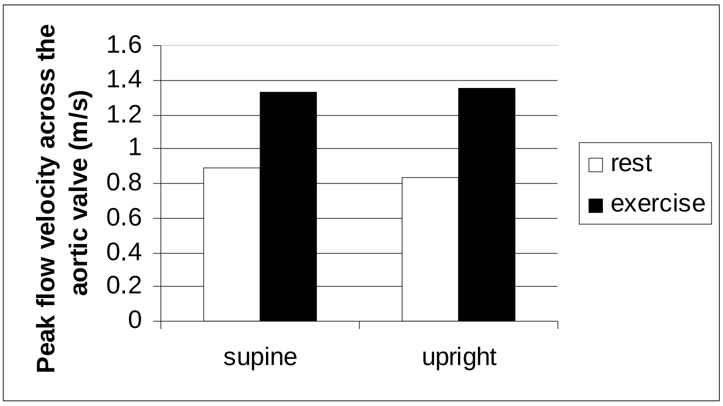

Figure (10): Peak flow velocity through aortic valve in supine and upright positions at rest and during exercise.

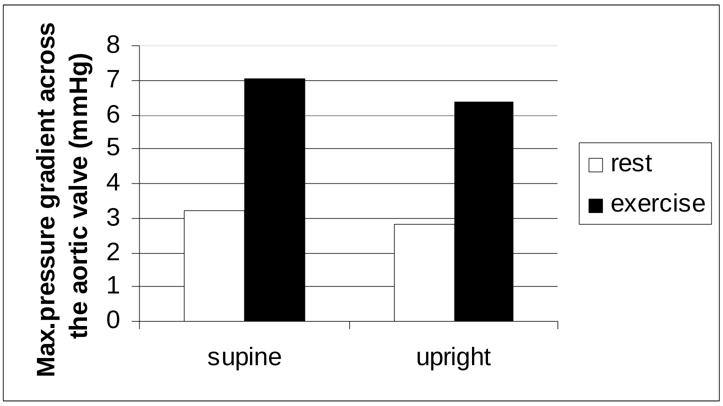

Figure (11): Maximum pressure gradient across the aortic valve in supine and upright positions at rest and during exercise.

2- Cardiovascular reflex responses to the difference between the differences of supine and upright exercise:

On comparison of the differences of the cardiovascular reflex responses to exercise between supine and upright positions indicate that they are significantly lower in HR, SBP and PVR but significantly higher in CO, DBP and ET in supine position in comparison with the upright positions.

There are no significant changes in other variables which include SV, MBP, VTI, Vmx and PGmx.

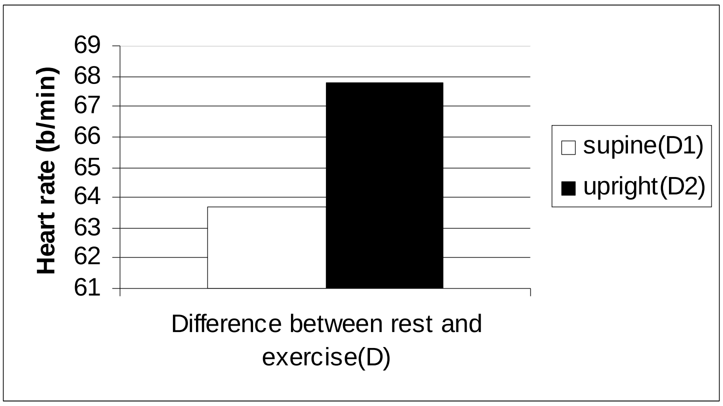

Figure (12): Heart rate differences in response to exercise in supine and upright positions.

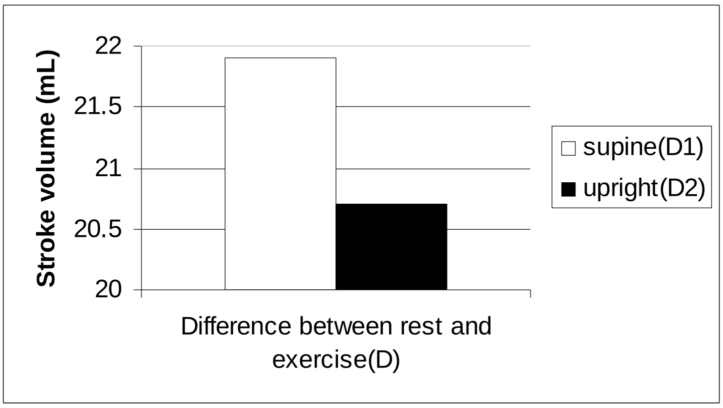

Figure (13): Stroke volume differences in response to exercise in supine and upright positions.

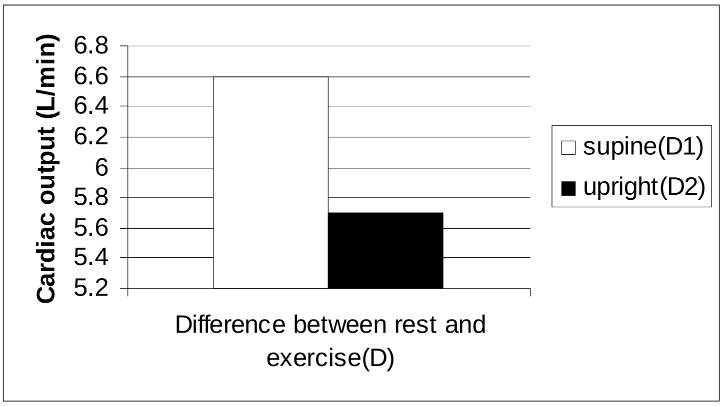

Figure (14): Cardiac output differences in response to exercise in supine and upright positions.

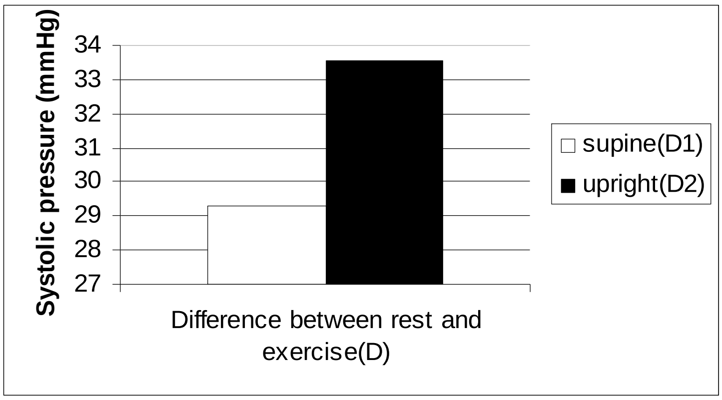

Figure (15): Systolic blood pressure differences in response to exercise in supine and upright positions.

Figure (16): Diastolic blood pressure differences in response to exercise in supine and upright psitions.

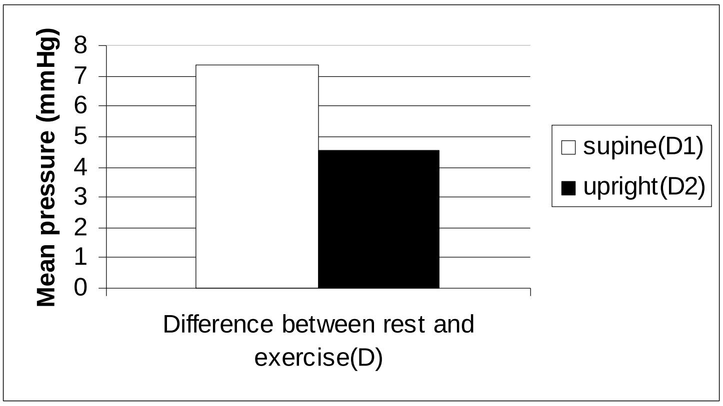

Figure (17): Mean blood pressure differencesin response to exercise in supine and upright positions.

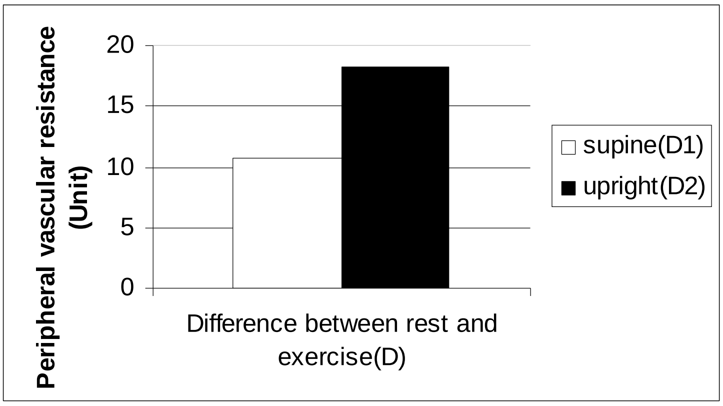

Figure (18): Peripheral vascular resistance differences in response to exercise in supine and upright positions.

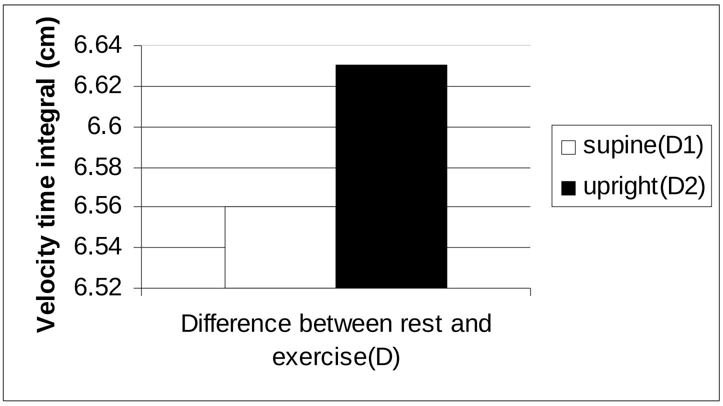

Figure (19): Velocity time integral differences in response to exercise in supine and upright positions.

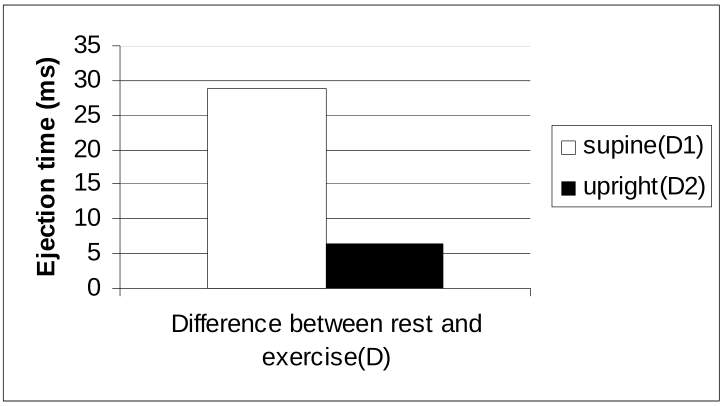

Figure (20): Ejection time differences in response to exercise in supine and upright positions.

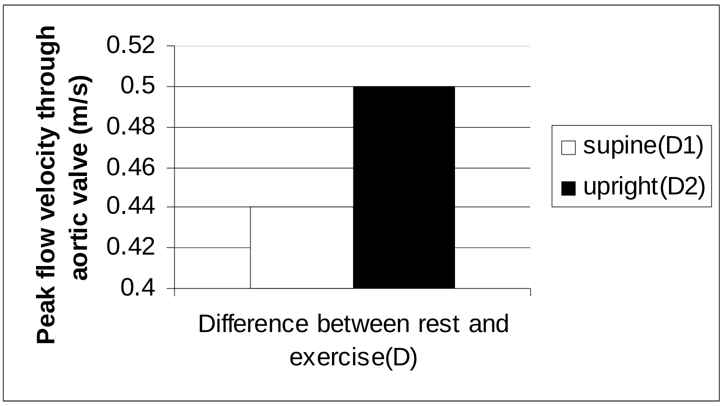

Figure (21): Peak flow velocity through aortic valve differences in response to exercise in supine and upright positions.

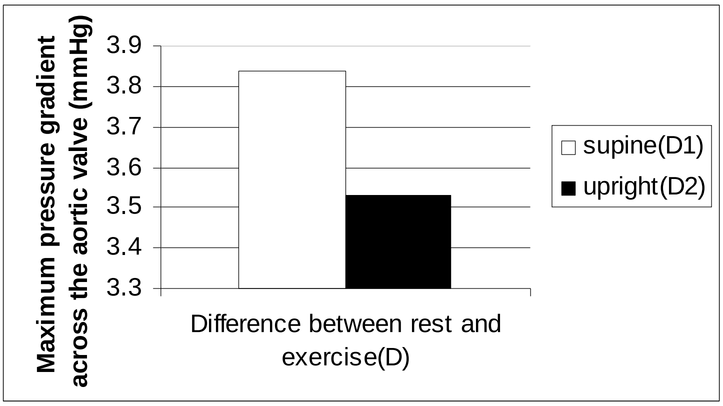

Figure (22): Maximum pressure gradient across the aortic valve differences in response to exercise in supine and upright positions.

3- Cardiovascular reflex responses to change in posture from supine to upright positions at rest and during exercise:

At rest, cardiovascular reflex responses to change in posture from supine to upright positions indicating that they are significantly higher in HR, DBP, MBP and PVR but significantly lower in SV, CO, VTI and ET in upright position in comparison with the supine position.

During exercise, a comparison of the cardiovascular reflex responses between supine and upright exercises indicates that they are significantly higher in HR, SBP and PVR but significantly lower in SV, CO and VTI in upright exercise on comparison with the supine exercise and there are no significant changes in DBP, MBP, ET, Vmx and PGmx between supine and upright exercises. Table (4) Figures.(22-32)

Discussion:

(2) At Rest :(Table 4) and Figures (22-32)

The change of the posture from the supine to upright position resulted in a significant increase in(9,11,12,16), (11,16), (11,16) (9,11,16) and (11,12) due to increasing sympathetic outflow.

But there is a significant decrease in (5,11,12) (4,9,11,12) (5,17,18) (5) due to pooling of blood from the upper to the lower part of the body (17) resulting in a decrease in venous return and cardiac output (18).

SBP slightly increases but does not reach to the significant level (11), but no significant decrease in **Vmx** and **PGmx** (19).

(2) Changes from Rest to Exercise :(Table (2) and Figures (11-21))

In response to exercise from rest condition, in both supine and upright positions, there are significant increases in HR, SV, CO, SBP, MBP, VTI, Vmx and PGmx. While DBP and PVR significantly decreased. However; ET decreases in both positions but is only significant in supine position.

Significantly increased in both positions because at the onset of exercise, there is a centrally mediated simultaneous activation of cardiovascular and motor centers, causing an initial rapid increase in HR due to withdrawal of parasympathetic efferent activity. Once HR reaches about 100 bpm, there is further increase in HR due to activation of cardiac sympathetic efferent activity.(4,5,12,14)

Significantly increased in both positions because during exercise, venous return increases because of an increase in the activity of the muscle venous pump in addition to increase in cardiac sympathetic efferent activity.(5,9,12,20)

Significantly increased in both positions due to an increase in HR and SV.(4,5,9)

Significantly increased in both positions due to the effect of increased sympathetic activity.(4,5,9)

Significantly decreased in both positions due to extreme vasodilatation that occurs in large masses of muscle. This result agrees with other previous studies.(4,5,11,12,14)

Significantly increased in both positions. (5,11,12,14)

Decrease in both positions due to increases in SV and/or increase in ejection rate, but is only significant in supine position. This result agrees with other previous studies in which ET significantly decreased in both positions.(3,15)

Significantly increased in both positions due to increase in SV. This result agrees with other previous studies.(3,15,19)

Significantly increased in both positions due to increase in SV. This result disagreement with the study of (15).

On comparison between supine and upright exercise (Table (4) and Figures (22-32), it was found that:

(4,14), (4,9) and PVR are significantly lower in supine than upright exercise.

(21), CO and VTI are significantly higher in supine than upright exercise.

~ DBP, MBP, ET, Vmx and PGmx do not significantly change.

But when comparing between the differences of the cardiovascular reflex responses to exercise between supine and upright positions (Table (3) and Figures (22-32), we found that:

~ HR, SBP and PVR are significantly lower in supine than upright exercises.

~ CO, DBP and ET are significantly higher in supine than upright exercises.(13)

While the differences of other variables SV(19), MBP, VTI(3), Vmx(19) and PGmx are not significantly different between both positions.

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