EFFECT OF VALSALVA MANEUVER AND BREATHING SYNCHRONISATION DURING HIGH INTENSITY CLOSED KINETIC CHAIN EXERCISES ON CARDIO-VASCULAR SYSTEM

EFECTUL MANEVREI VALSALVA ŞI A SINCRONIZĂRII RESPIRAŢIEI ÎN TIMPUL EXERCIŢIILOR ÎN LANŢ CINEMATIC ÎNCHIS, DE INTENSITATE MARE, ASUPRA SISTEMULUI CARDIOVASCULAR

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Key words: Valsalva maneuver, close kinetic chain exercises, cardiovascular parameters

Abstract. Several investigators have observed increased systolic (SBP) and diastolic blood pressure (DBP) in individuals performing high intensity CKC exercise. A number of high intensity CKC training experts believe that performing Valsalva maneuver actually benefits a weight lifter by stabilizing the spine and improving performance. These potential benefits must be weighed against the potential dangers of the exaggerated pressure response. SBP appears to climb during successive repetitions of the set and can reach very high values on the final repetition in certain individuals. **Purpose.** To determine if different breathing techniques affect BP response during high intensity CKC exercise. If this BP effect can be dampened, resistance exercise may be safer for all populations but especially for those who are untrained, at high risk for cardiovascular disease. **Methods.** A Cross over - experimental design was adopted, with 3 different breathing pattern coupled with high intensity exercise by the same subjects at different schedule. **Procedure:** Subjects were introduced to Borg's Rate Of Perceived Exertion (RPE) and were taught different breathing patterns - **Valsalva maneuver, Inspiration coupled with eccentric phase, Expiration coupled with eccentric phase** of high intensity close kinetic chain exercise. Blood pressure, heart rate and respiratory rate and numbers of repetitions performed were documented and analysed. **Conclusion.** Performing valsalva maneuver with the eccentric phase of high intensity close kinetic chain exercises, increases the cardiovascular parameters and the respiratory rate. The expiratory breathing pattern coupled with the eccentric phase of high intensity close kinetic chain exercises, shows increase in the cardiovascular parameters.

Cuvinte cheie: manevra Valsalva, exerciţii în lanţ cinematic închis, parametri cardiovasculari

Rezumat. Numeroşi investigatori au observat o creştere a tensiunii arteriale sistolice (TAS) şi diastolice (TAD) la indivizii care executau exerciţii în lanţ cinematic închis de intensitate mare. Un mare număr de antrenori experţi în antrenamentul cu exerciţii în lanţ cinematic închis cred că executarea manevrei Valsalva optimizează acţiunea de ridicare a greutăţior prin stabilizarea coloanei, îmbunătățind astfel performanţa. Acest potenţial beneficiu trebuie pus în balanţă cu eventualele pericole datorate răspunsului exagerat al tensiunii. TAS pare să crească în timpul repetiţiilor successive dintr-un set şi poate atinge valori foarte ridicate spre sfârşitul numărului de repetări la anumite persoane. **Scop.** Scopul lucrării este de a determina dacă diferitele tehnici de respiraţie afectează răspunsul tensiunii arteriale în timpul exerciţiilor în lanţ cinematic închis de intensitate mare. Dacă acest efect de creştere a TA poate fi redus, exerciţiile cu rezistenţă pot fi executate în siguranţă de oricine, dar mai ales de cei neantrenaţi, cu risc mare de boli cardiovasculare. **Metode.** S-a adoptat un design experimental încrucişat, cu 3 paternuri diferite de respiraţie cuplate cu exerciţiile de intensitate mare, executate de aceiaşi subiecţi, la ore diferite. **Procedură:** Subiecţii s-au familiarizat cu scala Borg a intensităţii efortului (SBIA/ RPE) şi li s-au arătat patternuri diferite de respiraţie – **manevra Valsalva, inspir cuplat cu faza excentrică, expir cuplat cu faza excentrică,** efectuate odată cu exerciţiile în lanţ cinematic închis de intensitate mare. TA, pulsul şi rata respiratorie şi numeroasele repetări au fost documentate şi analizate. **Concluzii.** Executarea manevrei Valsalva în faza excentrică a exerciţiilor în lanţ cinematic închis de intensitate mare cresc parametrii cardiovasculari şi rata respiratorie. Patternul expiraţiei cuplat cu faza excentrică a exerciţiilor în lanţ cinematic închis de intensitate mare, determină creşterea parametrilor cardiovasculari.

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Background

Exercise increases stress to the cardiovascular system. Isotonic exercise, which is defined as a muscular contraction resulting in movement, primarily provides a volume load to the left ventricle, and the response is proportional to the size of the working muscle mass and the intensity of exercise. Cardiac output in isotonic exercise is not increased as much as isometric exercises, because increased resistance in active muscle groups limits blood flow. [1] Exercises can be performed as an Open Kinetic Chain (OKC) activity, where the extremity can move in any direction freely, because it is not attached at the end. A Closed Kinetic Chain (CKC) activity, on the other hand, fixes the distal end of the extremity either to the ground or to a device that has a predetermined motion. [2]

Several investigators have observed increased systolic (SBP) and diastolic blood pressure (DBP) in individuals performing high intensity CKC exercise. This BP response presumably is caused in part by the increased vascular total peripheral resistance in the contracting muscle. In addition to this peripheral factor, the BP response may be augmented by increased intrathoracic pressure which occurs during forced exhalation against a closed airway (Valsalva maneuver) or by exhalation alone. Exhalation or breath-holding may add to the increased afterload on the heart and thus increase BP. On the other hand, inhalation, which decreases intrathoracic pressure and thus afterload, may help attenuate BP elevation associated with high intensity CKC exercise.[3]

A number of high intensity CKC training experts believe that performing the Valsalva maneuver actually benefits a weight lifter by stabilizing the spine and improving performance. These potential benefits must be weighed against the potential dangers of the exaggerated pressure response. SBP appears to climb during successive repetitions of the set and can reach very high values on the final repetition in certain individuals. Such maximal efforts perhaps should be reserved for young competitive athletes and others who require maximal strength gains for sport performance. [3]

The purpose of this study was to determine if different breathing techniques affected BP response during high intensity CKC exercise. If this BP effect can be dampened, resistance exercise may be safer for all populations but especially for those who are untrained, at high risk for cardiovascular disease, or have diagnosed cardiovascular disease.

Thus the **objectives** of the study were to find the effect of Valsalva maneuver, inspiration coupled with eccentric phase, expiration coupled with eccentric phase during high intensity closed kinetic chain exercise on cardiovascular parameters.

Previous literatures of **Steven T. Linsenbardt, Tom R. Thomas et al (1992)** in their study ‘Effect of breathing techniques on blood pressure response to resistance exercise’ concluded that the Valsalva maneuver exaggerates the blood pressure response to resistance exercise. Coupling inhalation or exhalation with the concentric phase of the lift produces similar cardiovascular responses. [4] **Andrea Di Blasio, Andrea Sablone et al (2009)** in their study ‘Arm *vs*. Combined Leg and Arm Exercise, Blood pressure responses and ratings of perceived exertion at the same indirectly determined heart rate’ stated that the right exercise prescription and effective exercise training require a pre-participation medical examination and a stress test, we can infer from our results that when a sedentary person exercises on an arm crank ergometer, without a specific stress test to provide the maximal HR and monitor the blood pressure response, it would be safer and healthier to monitor him/her according to the RPE scale**.** [5] Vatner SF**,** Pagani M**.**' in their study ‘Effects of Exercise Intensity and Body Position on CV Function During Resistance Exercise’ concluded that low intensity long duration resistance training elicits a greater systolic blood pressure response than high intensity short duration resistance training. It is speculated that the cause of this change seems to be due in part to increased cardiac output and a pressor reflex due to duration of exercise, not mechanical compression and the Valsalva maneuver as it had been previously reported. Heart rate also showed a greater increase at lower intensities. The increase seen at lower intensity was probably caused by the longer duration of the exercise at the lower intensity. Greater oxygen consumption and an increased sympathetic response account for the significantly greater heart rate response seen at lower intensities. [6]

Materials & Methodology

A Cross over - experimental design was adopted, with 3 different breathing pattern coupled with high intensity exercise by the same subjects at different schedule as planned to be performed. Medical and Paramedical Students of Dr. D. Y. Patil University, Pimpri, Pune & Padmashree Dr. D. Y. Patil Hospital, Pimpri, Pune, Simple Random Sampling was done for a sample size of 30 Healthy Males with no musculoskeletal injury / cardiovascular diseases / psychological problems and with normal vitals, age between 18yrs to 28yrs were included in the study. The samples were ensured that they do not participate in regular exercise program or intentional activities beyond normal daily habits to limit exercise bias. Subjects who are Smokers, diagnosed for any cardiopulmonary disease, asthma, bronchiectasis, congenital heart defici, hypertension, and history of common cold within the last 2 weeks were excluded.

The participants were examined and selected on the basis of inclusion & exclusion criteria. Oral information and importance of this study was explained in detail. Written consent was taken of all samples of this study. Also a written permission was taken from the Head of Department of ICU of Padmashree Dr. D. Y. Patil Hospital to use the ICU monitors. After identifying the subjects for experiment, the subjects were asked to perform leg-press exercise with maximal weights. Subjects were then introduced to Borg's Rate Of Perceived Exertion (RPE)[7] Scale and termination of exercise was allowed when they rated score 19 (i.e. very-very hard) on the Rate Of Perceived Exertion scale. This helped the subjects to get well – versed with the Borg's scale.

In the next session, the subjects were taught the coupling of different breathing patterns with the eccentric phase of high intensity close kinetic chain exercise. 1) **Valsalva maneuver procedure** comprised of coupling breath holding or Valsalva maneuver with the closed kinetic chain exercise i.e. floor push-ups. The breath holding was done during both eccentric and concentric phase of floor push-ups exercise. The subjects were asked to perform maximum repetitions possible. 2) **Inspiration coupled with eccentric phase** comprised of performing inspiration during eccentric contraction i.e. while going down to the floor followed by expiration while coming back to the starting position. The subjects were asked to perform maximum repetitions possible. 3) **Expiration coupled with eccentric phase** comprised of performing expiration during eccentric contraction i.e. while going down to the floor followed by inspiration while coming back to the starting position. The subjects were asked to perform maximum repetitions possible.

During each session, subjects were first taught the coupling of breathing pattern with the high intensity close kinetic chain exercise. This was practiced with the ECG leads placed on subject's chest and machine OFF. Once the subjects mastered the pattern, they were asked to perform one technique per day with machine ON. The cardiovascular parameters at its peak were noted while performing the eccentric phase of closed kinetic chain exercise i.e. push-ups.

Between each exercise testing session with a specific breathing technique, 1 day of rest was given to the subject. Hence, three different patterns were performed on three different days to avoid the 'Order Affect', and the subjects were given sequence of the procedure randomly by lottery method. Thus, all subject attended all 3 sessions of testing- Valsalva manouvre, Inspiratory technique, Expiratory technique coupled with exercises at varied sequences.

Subjects were asked to perform maximum repetitions possible. Blood pressure, heart rate and respiratory rate were recorded when it reached its peak while performing the exercise. Also numbers of repetitions performed were documented. The procedure was terminated when the subject reported score 19 on Borg's Rate of Perceived Exertion scale. The pre & post the cardiovascular parameters viz. Blood pressure, Heart rate, Respiratory rate were recorded as displayed in the monitor and Number of repetitions performed was noted and were analyzed

Data analysis & result

ANOVA, Analysis Of Variance is the parametric equivalent of the Friedman test. [8]

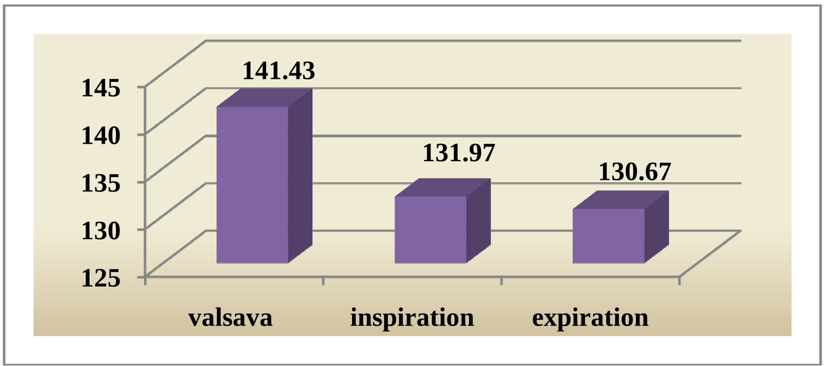
ANOVA for related and matched subject is used for one subject group in three or more conditions, and the results from these conditions are compared for differences between them. As the subjects are same, there is minimal chance of error between the groups. In the present study, all 3 procedures (valsalva, inspiratory pattern, expiratory pattern) were done on the same subject. So there is no chance of error or variability between the groups. So in this study one-way ANOVA is most appropriate statistical test which will compare the differences between three procedures

All the statistical tests are compared at confidence interval of 95%. Mean systolic blood pressure were 141.43, 131.97 and 130.67 mmHg following Valsalva maneuver, Inspiratory and expiratory pattern respectively. The resulting F value of 6.48 was significant at P=0.002. Mean diastolic blood pressure were 76.63, 72.10 and 70.23 mmHg after Valsalva maneuver, Inspiratory and expiratory pattern respectively. For this the F value 2.368 was significant at P=0.100. Mean pulse rate were 159.83, 147.10 and 128.90 beats/min after Valsalva maneuver, Inspiratory and expiratory pattern respectively. The calculated F value 38.49 was significant at P < 0.0001. Mean respiratory rate were 46.03, 31.73 and 38.30 breaths/min after Valsalva maneuver, Inspiratory and expiratory pattern respectively. The resulting F value 6.35 was significant at P=0.002. Mean repetitions were 18.60, 16.23 and 15.76 after Valsalva maneuver, Inspiratory and expiratory pattern respectively. The resulting F value 0.8306 was significant at P=0.44.

Table: 1 Comparison of systolic blood pressure in valsalva, inspiratory and expiratory breathing pattern

Pattern of breathing	N	Mean diff In mmHg	SD	ANOVA	P
1 (valsalva)	30	141.43	13.4	F=6.488	0.002
2 (inspiratory)	30	131.97	9.67		
3 (expiratory)	30	130.67	14.3		

Table 1, shows the mean systolic blood pressure in all 3 breathing patterns. As shown in the table, the mean valsalva pattern is the highest and the mean expiratory pattern is the lowest. By using one - way ANOVA, the F value is highly significant.



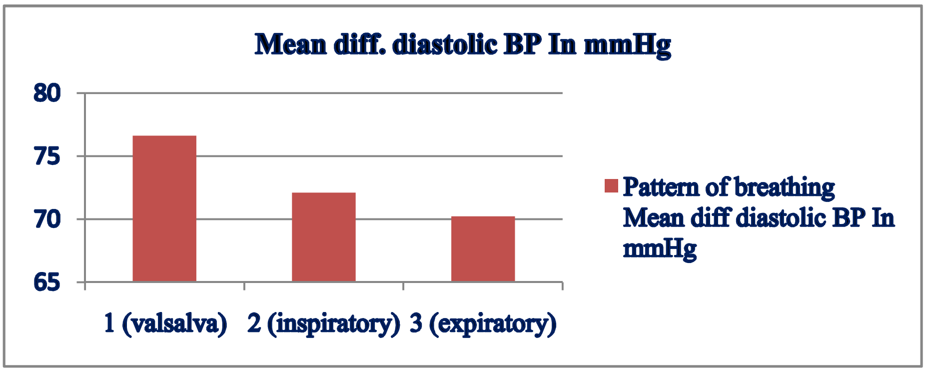
Graph: 1 Comparison of systolic blood pressure in valsalva, inspiratory and expiratory breathing pattern

In graph 1, there is mean systolic blood pressure during each breathing pattern which shows expiratory pattern affects systolic blood pressure least during high intensity close kinetic chain exercises.

Table. 2 Comparison of diastolic blood pressure in Valsalva, inspiratory and expiratory breathing pattern

Pattern of breathing	N	Mean diff diastolic BP In mmHg	SD	ANOVA	P
1 (valsalva)	30	76.63	9.66	F=2.368	0.100
2(inspiratory)	30	72.10	11.3		
3 (expiratory)	30	70.23	13.8		

Table 2, shows the mean diastolic blood pressure in all 3 breathing patterns. As shown in the table, the mean valsalva pattern is the highest and the mean expiratory pattern is the lowest.



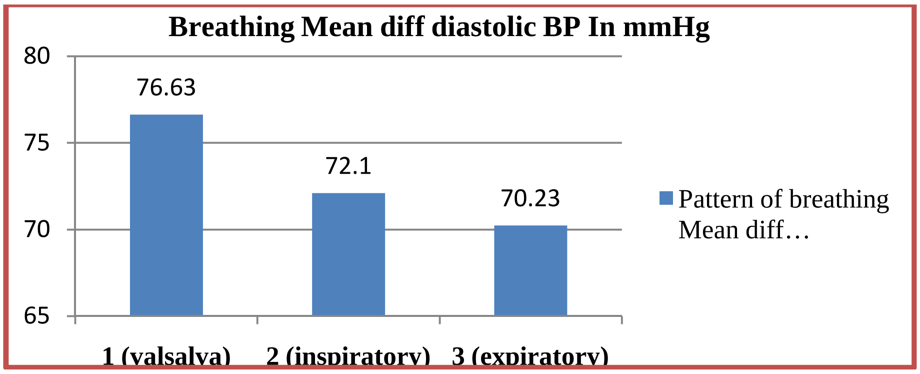
Graph. 2 Comparison of diastolic blood pressure in Valsalva, inspiratory and expiratory breathing pattern.

In graph 2, there is mean diastolic blood pressure during each breathing pattern which shows expiratory pattern affects diastolic blood pressure least during high intensity close kinetic chain exercises.

Table. 3 Comparison of pulse rate in Valsalva, inspiratory and expiratory breathing pattern.

Pattern of breathing	N	Mean In Pulse rate	SD	ANOVA	P
1 (valsalva)	30	159.83	11.6	F=38.49	<0.0001
2 (Inspiratory)	30	147.1	13.9		
3 (expiratory)	30	128.9	15.4		

Table 3, shows the mean pulse rate in all 3 breathing patterns. As shown in the table, the mean valsalva pattern is the highest and the mean expiratory pattern is the lowest. By using one - way ANOVA, the F value is highly significant at $P < 0.0001$.



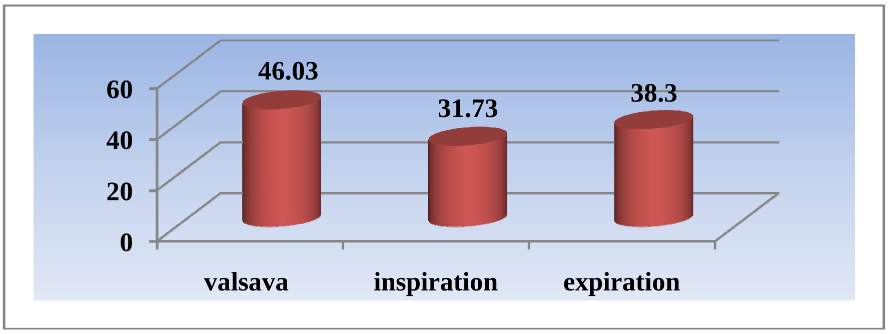
Graph. 3 Comparison of pulse rate in valsalva, inspiratory and expiratory breathing pattern

In graph 3, there is mean pulse rate during each breathing pattern which shows expiratory pattern affects pulse rate least during high intensity close kinetic chain exercises.

Table. 4 Comparison of respiratory rate in valsalva, inspiratory and expiratory breathing pattern

Pattern of breathing	N	Mean diff In mmHg	SD	ANOVA	P
1 (valsalva)	30	46.03	17.9	F=6.35	0.002
2 (inspiratory)	30	31.73	11.9		
3 (expiratory)	30	38.30	16.2		

Table 4, shows the mean respiratory rate in all 3 breathing patterns. As shown in the table, the mean valsalva pattern is the highest and the mean inspiratory pattern is the lowest. By using one - way ANOVA, the F value is highly significant.



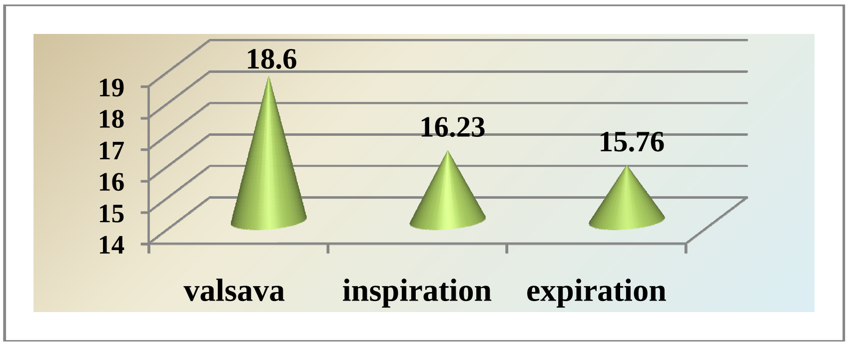
Graph. 4 Comparison of respiratory rate in valsalva, inspiratory and expiratory breathing pattern

In graph 4, there is mean respiratory rate during each breathing pattern which shows expiratory pattern affects respiratory rate least during high intensity close kinetic chain exercises.

Table. 5 Comparison of repetitions in valsalva, inspiratory and expiratory breathing pattern

Pattern of breathing	N	Mean diff In mmHg	SD	ANOVA	P
1 (valsalva)	30	18.60	10.8	F=0.8306	0.44
2(inspiratory)	30	16.23	8.21		
3 (expiratory)	30	15.76	8.11		

Table 5, shows the mean repetitions in all 3 breathing patterns. As shown in the table, the mean valsalva pattern is the highest and the mean expiratory pattern is the lowest. By using one - way ANOVA, the F value is not significant.



Graph. 5 Comparison of repetitions in valsalva, inspiratory and expiratory breathing pattern

Graph 5, shows the mean repetitions of the exercise performed during different breathing patterns.

Discussion

The major cardiovascular responses to dynamic-aerobic exercise (endurance exercise) are increases in oxygen uptake (VO_2), cardiac output, and heart rate (HR). There is a progressive increase in systolic blood pressure (SBP), with maintenance of or a slight decrease in diastolic blood pressure (DBP), resulting in a concomitant widening of the pulse pressure and a modest increase in mean pressure, with a decrease in peripheral vascular resistance.[9]

In the early phases of exercise in the upright position, cardiac output is increased by an augmentation in stroke volume mediated through the use of the Frank-Starling mechanism and heart rate; the increase in cardiac output in the latter phases of exercise is primarily due to an increase in heart rate. At fixed submaximal workloads below ventilatory threshold in healthy persons, steady-state conditions are usually reached within minutes after the onset of exercise; after this occurs, heart rate, cardiac output, blood pressure, and pulmonary ventilation are maintained at reasonably constant levels. During strenuous exertion, sympathetic discharge is maximal and parasympathetic stimulation is withdrawn, resulting in vasoconstriction in most circulatory body systems, except for that in exercising muscle and in the cerebral and coronary circulations. As exercise progresses, skeletal muscle blood flow is increased, oxygen extraction increases as much as 3-fold, total calculated peripheral resistance decreases, and systolic blood pressure, mean arterial pressure, and pulse pressure usually increase. Diastolic blood pressure may remain unchanged or decrease to a minimal degree.

The pulmonary vascular bed can accommodate as much as a 6-fold increase in cardiac output without a significant increase in pulmonary artery pressure. In normal subjects, this is not a limiting determinant of peak exercise capacity. Cardiac output can increase as much as 4- to 6-fold above basal levels during strenuous exertion in the upright position, depending on genetic endowment and level of training. In the post-exercise phase, hemodynamic return to baseline within minutes of termination. Vagal reactivation is an important cardiac deceleration mechanism after exercise; it is accelerated in well-trained athletes but may be blunted in deconditioned and/or “medically ill” patients. [10]

Heart Rate Response: The immediate response of the cardiovascular system to exercise is an increase in heart rate due to a decrease in vagal tone. This increase is followed by an increase in sympathetic outflow to the heart and systemic blood vessels. During dynamic exercise, heart rate increases linearly with workload and $VO_{2.}$ Dynamic exercise increases heart rate more than isometric or resistance exercise.[10] **Arterial Blood Pressure Response:** Systolic blood pressure rises with increasing dynamic work as a result of increasing cardiac output, whereas diastolic pressure usually remains about the same or moderately lower, and it may be heard to zero in some normal subjects. [11] **Blood Pressure:** At rest, a typical **systolic** blood pressure in a healthy individual ranges from 110-140mmHg and 60-90mmHg for **diastolic** blood pressure. During exercise systolic pressure, the pressure during contraction of the heart (known as systole) can increase to over 200mmHg and levels as high as 250mmHg have been reported in highly trained, healthy athletes. Diastolic pressure on the other hand remains relatively unchanged regardless of exercise intensity. In fact an increase of more than 15 mm Hg as exercise intensity increases can indicate coronary heart disease and is used as marker for ceasing an exercise tolerance test. Both systolic and diastolic blood pressure can rise to high, albeit brief, levels during resistance exercise. Values of 480/350mmHg have been reported to coincide with a **Valsalva maneuver** - i.e. trying to exhale against a closed mouth, nose and glottis. [12]

The impact of the Valsalva maneuver (a forced expiration is invoked against a closed glottis) and high levels of muscle tension to lift or otherwise move a heavy weight can result in somewhat dramatic changes to the physiological responses to resistance training. Depending on the duration and intensity of the maneuver and the resistance, an increase in intrathoracic pressure leading to decreased venous return and potentially reduced cardiac output may occur.

The physiological responses are an increase in HR to maintain cardiac output and vasoconstriction to maintain blood pressure, which otherwise may decrease with decreasing cardiac output. At the release of the “strain,” venous return is dramatically increased, increasing cardiac output, which circulates through a somewhat constricted arterial vascular system. The result is a rise in blood pressure, potentially quite dramatic, that may require minutes to return to baseline. During heavy resistance exercise and especially if accompanied by the Valsalva maneuver, symptoms of light headedness or dizziness may occur if cardiac output is reduced. With relaxation, individuals may experience headache while pressure remains elevated. In patients with heart disease, symptoms of myocardial ischemia may ensue as a result of elevated blood pressure and increased myocardial work. When heavy dynamic-resistance exercise (strength exercise) such as lifting weights is performed, the cardiovascular responses are a combination of the responses that occur during both dynamic-aerobic exercise and isometric exercise, reflecting a combined volume and pressure load. The level of the developed pressure load depends on the magnitude of the resistance required and the duration of the muscle contraction in relation to the intervening rest period.

Thus, a smaller pressure load on the cardiovascular system will occur during this type of exercise if the relative resistance is not too great, the contraction period is relatively short (1 to 3 seconds), and there is at least a 1- to 2-second rest period between contractions. The magnitude of the volume load on the cardiovascular system during a dynamic-resistance exercise will be greater when the magnitude of the resistance is relatively low (able to complete 20 to 30 repetitions) and the contractions are performed every few seconds.

Specifically, and again depending on the duration and intensity of the resistance exercise, heart rate can substantially increase and may approach age-predicted maximum, that is, heart rate achieved with treadmill exercise testing. Blood pressure responses, both systolic and diastolic, may potentially surpass values achieved during standard exercise testing.

Whereas, diastolic blood pressure would be expected to decrease or not change with aerobic exercise, substantial rises in diastolic blood pressure have been observed with resistance training. However, it must be underscored that such potential heart rate and blood pressure responses are very unlikely to occur with appropriate instruction and supervision of resistance training participants because of relatively moderate intensities of effort. [9]

Conclusion

This study concludes that it is important to couple breathing with the high intensity close kinetic chain exercises. Performing Valsalva maneuver with the eccentric phase of high intensity close kinetic chain exercises increases the cardiovascular parameters and the respiratory rate.

The expiratory breathing pattern coupled with the eccentric phase of high intensity close kinetic chain exercises, shows increase in the cardiovascular parameters but not as much as the increase found on performing Valsalva maneuver during the high intensity close kinetic chain exercises.

Coupling the inspiratory breathing pattern with the eccentric phase of high intensity close kinetic chain exercises, do increases the cardiovascular parameters but less than on performing valsalva maneuver and more than on coupling expiratory breathing pattern with the eccentric phase of the high intensity close kinetic chain exercises.

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