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THE EFFECT OF DIFFERENT ISOKINETIC TRAINING PROTOCOLS ON CARDIOVASCULAR VARIABLES IN ADULT POPULATION.

Physiotherapy

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ABSTRACT

Objective: The aim of the study was to compare the effects of different isokinetic training protocols on cardiovascular variables. *Method:* In the present study 60 subjects, 28 males and 32 females were selected. The subjects performed two isokinetic strength training protocols with angular velocities in reverse order - 1st protocol was done at 60°/s, 120°/s and 180°/s and the 2nd protocol at 180°/s, 120°/s and 60°/s on Biodex Isokinetic dynamometer system 4 pro. HR was measured before, during and after completion of each protocol. In recovery period BP and HR were recorded for 5 minutes after completion of each protocol. *Results:* The result of present study shows significant difference in HRmax and HRR when two different isokinetic training protocols are used. But there is no significant difference in SBP and DBP. *Conclusion:* Different orders of velocities in isokinetic training will have different effect of cardiovascular variables.

KEYWORDS:

angular velocity, cardiovascular variables, heart rate, isokinetic training

INTRODUCTION

Isokinetic exercise was introduced by Hislop and Perrine in 1967 and it is an accommodating resistive exercise in which subject works maximally against pre set velocity of machine[1]. Muscular activity is related to excitability, contractility and production of strength/torque. Both concentric and eccentric contractions can be used under isokinetic exercises in different orders[2,3]. Under isokinetic condition open or closed kinematic chain exercise can also be performed.[4]

An Isokinetic condition allows to study the peak torque (PT) values and average strength which is expressed as newton meters (Nm) produced by the exercising muscle. Relative torque (RT) is an indirect value which can also be calculated from values of torque per kg of body mass (Nm/Kg). It also measures work expressed in joules (J). These measurement determines PT angle which is expressed in degrees (^{0}), preset angular velocity (^{0}/s), power expressed in watts (w)[2,5].

As a result of development of isokinetic dynamometer considerable research on the in vivo characteristics of human muscles has been initiated. Also, isokinetic dynamometer has a lot of clinical application in rehabilitation, strength and endurance testing.[6]

Isokinetic training differs markedly from isometric and traditional resistance training methods. Isokinetic exercise doesn't require a specified initial resistance unlike traditional resistance exercise, rather isokinetic device controls velocity of the movement. As a result muscle exerts maximal force throughout the ROM. Exerting maximal force throughout the ROM results in optimal strength development.[7]

There is little reported data on the associated cardiovascular effects of maximal isokinetic testing particularly in the non athletic individuals. An understanding of cardiovascular responses to various modes of exercise is important to physiotherapists who are involved in supervising strength and endurance testing and prescribing exercise programs.

Heart rate can be easily measured by using wireless portable sensor so, it has been extensively used to monitor exercise intensity and estimate exercise response[8,9] exercise expenditure[10] and cardiac output[11,12]. A decline in heart rate after exercise occurs due to autonomic activity i.e. parasympathetic reactivation[13]. A delayed heart rate recovery after exercises has been associated with impaired functional capacity and poor prognosis among people with or without cardiovascular disease[14,15].

Submaximal dynamic exercise induces greater arterial pressure responses than isometric exercise of same intensity and also submaximal endurance exercises for rehabilitation yields an elevated functional stress on the cardiovascular system which could precipitate hazardous events particularly in subjects with unrecognized cardiac diseases[16].

Present cardiovascular status among young adults in India necessitates the need to determine the cardiovascular effects following different isokinetic training protocols. This may help to establish reference values for normal healthy subjects and could serve as basis for monitoring subjects to ensure patient safety. Also the protocol posing least cardiovascular stress can be recommended to population at low cardiorespiratory fitness.

METHODOLOGY

SUBJECTS

60 subjects were selected (32 females and 28 males) between ages of 20 and 30 years whose BMI was between normal range (18.5 to 24.9 kg/m^2) from Jamia Hamdard University. Subjects who had history of smoking, hypertension, recent history of any health problem that might affect the ability to perform physical activity were excluded from the study.

PROCEDURE

All the subjects were informed in detail about the type and nature of the study prior to the test and then consent for the study was also taken.
First of all the heart rate and blood pressure were measured of each subject and then 15 minutes of rest was given in supine position followed by measurement of heart rate and blood pressure again. Next the subjects were given hamstring and quadriceps stretching standardized to 3 reps with 30 seconds hold. Next the subjects warmed up for 5 minutes on treadmill at 3.5 kmph[17]. Following warm-up heart rate and blood pressure readings were again noted.

Two different protocols of strength measurement of muscles of the knee joint under isokinetic condition were used. The testing was carried out in sitting position. Before starting the test, dominant leg of subject was determined by asking the subject to kick a football. All the subjects were randomly divided into two groups (Group A and Group B) by tossing a coin. With head, the subject was assigned to group A and with tail to group B. Random allocation was done to nullify the order effect. Group A performed protocol 1 first and then protocol 2. Group B performed protocol 2 first and then protocol 1. After that the test was initiated. The dynamometer axis was in accordance with the anatomic axis of knee joint examined. Height of chair was adjusted according to the subject's height. Shoulder straps, thigh straps and ankle cuff were used to minimize the extraneous movement. The subject performed set of repetitions involving alternate extension-flexion of knee joint. The subject started the series of repetition with a "start" command and ended it with the "stop" command. The set of repetition was preceded with a trial repetition. Between trial repetition and test there was a 10 seconds break.

The **first protocol** contained 3 sets of the repetitions of alternate extension and flexion of knee joint. The first set was performed at angular velocity of 60^0/sec, second was performed at120^0/sec and third at 180^0/sec. In first set subjects performed 5 reps, in second set 10 reps and in 3^{rd} set 15 reps. A rest interval of 30 seconds was given between the sets. Between the two protocols a minimum of 15 minutes rest was given to the subjects or till the time their heart rate reached the pre exercise level.

In **second protocol** the time of rest interval between the sets was same as in protocol 1 and the sequence was reversed. The first set was performed at 180º /s, second was performed at 120º /s and the third set was performed at 60º /s with number of repetitions also reversed i.e. 15, 10 and 5 respectively.

Subject started the test depending upon his/her group. Highest value of heart rate (HRmax) was recorded at each velocity. During the 30 second rest interval between the sets heart rate value in the last 10^{th} second (HRbreak) was also recorded. Immediately after completion of the protocol blood pressure was recorded and then blood pressure readings were taken at 2^{nd} and 4^{th} minute in the recovery period. Heart rate recovery was also noted after every one minute for 5 minutes. After the stipulated rest interval second protocol was started and same readings were taken.

RESULTS

Statistical analysis was done with the help of Data Analysis component of Microsoft Excel 2013 version software. Cardiovascular variables were compared between the two protocols using the paired t-test. A p value of ≤ 0.05 was considered as statistically significant.

Comparison between protocol 1 and protocol 2

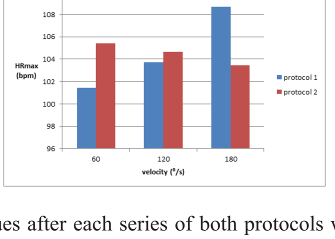
The mean HR rest value obtained for 60 subjects equaled 74.13 bpm. Mean heart rate values post warm up raised upto 91.30 bpm. Maximal heart rate values obtained at different angular velocities during protocol 1 were compared with maximal heart rate values at same angular velocities during protocol 2 (refer to table 1 and fig. 1). HRmax at 60°/s of protocol 1 was compared with HRmax at 60°/s of protocol 2. Similarly HRmax at 120°/s and 180°/s of protocol 1 and 2 were compared respectively. Mean value of HRmax at 6o°/s of protocol 1 was x= 101.45±14.398 and of protocol 2 was x= 105.40±15.214. Mean value of HRmax at 120°/s of protocol 1 was x=103.73±13.765 bpm and of protocol 2 was x= 104.65±12.250. Mean value of HRmax at 180°/s of protocol 1 was x= 108.66±14.92 bpm and of protocol 2 was 103.47±12.14 bpm. Comparison of HRmax at 60°/s and 180°/s came out to be statistically significant (p<0.05) at t- value 2.515 and 4.384 respectively. Comparison of HRmax at 120°/s came out to be statistically non-significant (p>o.o5) at t value 0.676.

Table1. Comparison between the mean values (x), standard deviation (SD) and significance level (p) for difference in maximal HR values obtained in both protocols with preset angular velocities of 60 °/s, 120 °/s and 180 °/s. N=60

Angular velocity (°/s)	Protocol 1		Protocol 2		t value	P value
	Mean	SD	Mean	SD		
1. 60°/s	101.45	14.39	105.4	15.21	2.515**	0.014
2. 120°/s	103.73	13.76	104.65	12.25	.676 NS	0.501
3. 180°/s	108.66	14.92	103.47	12.14	4.384**	.000

NS – not significant (p>0.05), ** - significant (p<0.01)

Fig. 1. Comparison between the maximal HR obtained in protocols 1and 2 during preset angular velocities of 60 °/s, 120 °/s and 180 °/s.



HR break values after each series of both protocols were compared with each other (refer table 2). Mean value of HR 10s break at 60°/s of protocol 1 was x= 94.30+12.361 bpm and that of protocol 2 was x= 96.30+11.827 bpm. Mean value of HR 10 s break at 120°/s of protocol 1 was x= 99.08+12.481 bpm and of protocol 2 was x= 98.65+12.316 bpm. Mean value of HR 10s break at 180°/s of protocol 1 was x= 97.97+12.097 and protocol 2 was x= 96.08+1.651 Comparison of all three HRbreak values came out to be statistically non significant (p>0.05) at t value 1.743, .486 and 1.81 respectively.

Table2. Comparison between the mean values (x), standard deviation (SD) and significance level (p) for difference in HRbreak values obtained in both protocols at the last 10th sec of 30 sec break between the preset angular velocities of 60 °/s, 120 °/s and 180 °/s. N=60

HRbreak	Protocol 1		Protocol 2		t value	P value
	Mean	SD	Mean	SD		
1. HR 10 sec break 60 °/s	94.30	12.36	96.30	11.82	1.744 NS	0.086
2. HR 10 sec break 120 °/s	99.08	12.48	98.65	12.31	.487 NS	0.628
3. HR 10 sec break 180 °/s	97.97	12.09	96.08	11.65	1.812 NS	0.075

NS – not significant (p>0.05)

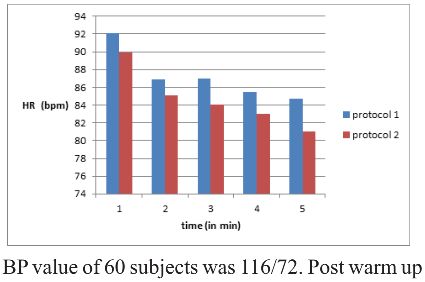
HRR values after completion of each protocol was taken for 5 minute and these values were compared with each other (refer to table 3 and graph 3). Mean values of HRR 1st min, 2nd min, 3rd min, 4th min and 5th min of protocol 1 were x=92.05+12.20 bpm, x= 86.93+11.99 bpm, x= 87.02+11.14 bpm, x= 85.50+10.94 bpm and x= 84.70+10.95 bpm respectively. Mean values of HRR 1st min, 2nd min, 3rd min, 4th min and 5th min of protocol 2 were x= 89.95+12.54 bpm, x=85.13+10.91bpm, x= 84.90+11.50 bpm, x=83.00+10.84 bpm and x= 81.03+11.15 bpm respectively. Statistically significant difference was found between the comparison of all 5 min recovery values of protocol 1 and 2 with t value 2.081, 2.390, 2.527, 3.69 and 4.627 respectively.

Table 3. Comparison between the mean values (x), standard deviation (SD) and significance level (p) of heart rate recovery after the completion of protocol 1and 2. N=60

HRR (for 5 min)	Protocol 1		Protocol 2		t value	P value
	Mean	SD	Mean	SD		
1. 1st min	92.05	12.20	89.95	12.54	2.081*	0.041
2. 2nd min	86.93	11.99	85.13	10.91	2.390*	0.020
3. 3rd min	87.02	11.14	84.09	11.50	2.527**	0.014
4. 4th min	85.50	10.94	83.00	10.84	3.69**	.000
5. 5th min	84.70	10.95	81.03	11.15	4.627**	.000

** - significant (p<0.05), ** - significant (p< 0.01)*

Fig 2. Comparison of the values of heart rate recovery between protocol 1 and 2.



The mean BP value of 60 subjects was 116/72. Post warm up the mean value raised upto 126.66/78.18. BP after completion of each protocol was recorded at three stages, first immediately after completion of protocol (BP 30s), then at 2^{nd} minute (BP 2 min) and at 4^{th} minute (BP 4 min). SBP at three stages after completion of protocol 1 were compared with respective SBP values of protocol 2 (refer table 4). Mean values of SBP 30s, 2^{nd} min and 4^{th} minute of protocol 1 were x= 123.47±11.83 mmhg, x=117.83±11.08 mmhg and x=117.07±11.30 mmhg respectively. Mean values of SBP 30s, 2^{nd} min and 4^{th} minute of protocol 2 were x=122.93±13.47 mmhg, x= 117.40±11.64 mmhg and x= 117.02±11.86 mmhg respectively. Comparison of all three readings of SBP came out to be statistically non-significant (p>0.05) at t- value 0.486, 0.465 and 0.046 respectively

Table4. Comparison between mean values (x), standard deviation (SD) and significance level (p) of SBP after completion of protocol 1 and 2. N=60

SBP (mmhg)	Protocol 1		Protocol 2		t value	P value
	Mean	SD	Mean	SD		
1. At 30th sec	123.47	11.83	122.93	13.47	0.486 NS	0.628
2. At 2nd min	117.83	11.08	117.40	11.64	0.465 NS	0.643
3. At 4th min	117.07	11.30	117.02	11.86	0.046 NS	0.962

NS – not significant (p>0.05)

DBP at three stages after completion of protocol 1 was compared with DBP of protocol 2 (refer table 5). Mean values of DBP 30s, 2nd min and 4th minute of protocol 1 were x= 77.88±6.63 mmhg, x=76.62±6.59 mmhg and x= 76.22±7.80 mmhg respectively. Mean values of DBP 30s, 2nd min and 4th minute of protocol 2 were x= 77.13±8.61 mmhg, 75.47±8.67 mmhg and 75.25±7.59 mmhg respectively. Comparison of all three readings of DBP came out to be statistically not significant (p>0.05) at t- value 1.002, 1.379 and 0.88 respectively.

Table 5. Comparison between the mean values (x), standard deviation (SD) and significance level (p) of DBP after the completion of protocol 1 and 2 N=60

DBP (mmhg)	Protocol 1		Protocol 2		t value	P value
	Mean	SD	Mean	SD		
1. At 30th sec	77.88	6.63	77.13	8.61	1.002 NS	0.320
2. At 2nd min	76.62	6.59	75.47	8.67	1.379 NS	0.172
3. At 4th min	76.22	7.80	75.25	7.59	0.88NS	0.382

NS – not significant (p>0.05)

DISCUSSION

The goal of the present study was to find out the effect of different (protocol 1 and protocol 2) isokinetic knee extension- flexion training protocols on cardiovascular variables in adult population so that the protocol with least cardiovascular stress could be determined. Data analysis was done between the protocol 1 and 2.

The result of analysis showed that there was statistical significant difference between the HRmax and HRR values of the two protocols; BP values didn't show any significant difference.

Comparison between the protocols

The mean HRmax values at different velocities when compared with the respective velocities between the two protocols (refer table 1 and graph 1) showed statistically significant difference in the two sets of velocities i.e. 60°/s and 180°/s but the comparison between the HRmax values at 120°/s didn't show statistical significant difference; also the values didn't exceed the accepted submaximal values for both the protocols.

In protocol 1 where first set of the series was of 60°/s the HRmax value was lower than the HRmax value at 60°/s set of protocol 2 where the set was last in the series. Similarly when HRmax value during the set of 180°/s was compared between the two protocols, it showed lower value in protocol 2 where the set was performed first in the series as compared to protocol 1 where the set was last in the series. The additive effect of previous two sets could be responsible for higher values of HRmax at same velocity between the two protocols.

Similar results were found by Duvaliet A et. al. , they concluded that isokinetic exercise is of dynamic nature therefore cardiovascular response is function of duration and number of movement.[18] Similar relation between number of repetition and effect on cardiovascular variables during isokinetic training was found by Degache et al in 2009.[19]

SBP and DBP showed no significant difference between the protocols. SBP and DBP values were almost same after completion of each protocol. SBP and DBP continued to decrease after completion of protocol 1 and 2.

It is seen that after a bout of light to moderate intensity exercise, SBP temporarily decreases below pre exercise levels for up to 12 hours in normal and hypertensive subjects. Pooling of blood in the visceral organs and lower limbs during recovery reduces central blood volume, which contributes to lowering of blood pressure.[7]

In HRR values significant difference was seen between the protocols (refer table 2 and graph 2). At first minute of recovery period following protocol 1 the HR value was higher than both the resting and post warm up values whereas in protocol 2 at first minute of recovery the HR value was more than resting HR but less than post warm up HR.

At first minute following completion of protocol 1 there was decline in HR value by 16.61 bpm from HRmax at the last set of protocol 1 and following protocol 2 HR value at first minute in recovery period declined by 15.45 bpm. Similar results were found by Dimpka et al in 2009 who found out that at the end of an exercise a decrease of 15-20 bpm in first minute of recovery is typical for healthy person.[20] In a study by Christopher R. Cole et al. a reduction in the heart rate by 12 beats per minute after the cessation of exercise was considered as an insignificant value for the recovery of the heart rate.[21]

At 1st, 2nd, 3rd, 4th and 5th minute of the recovery following protocol 1 the HR value was 92.05, 86.93, 87.02, 85.50 and 84.70 respectively whereas after protocol 2 the HRR values at 1s, 2nd, 3rd, 4th and 5th min of recovery was 89.95, 85.13, 84.09, 83.00 and 81.03 bpm respectively.

Okamoto T. et al concluded that cardiovascular response during exercise is directly related to the intensity, duration and degree of muscle mass recruited during exercise.[22]

A study in 2005 evaluated the heart rate recovery after exercise and neural regulation of heart rate variability in female marathon runners. It was found in the study that the HRR after exercise depends on several factors: the intensity of exercise, the cardiorespiratory fitness, cardiac ANS modulation, hormonal changes and baroreflex sensitivity. Different degrees of intensity of exercise would result in different effects on HRR.[23]

The significant differences noted between two protocols might be explained by the force-velocity and power-velocity curvilinear relationships reported in the physiological literature.[7] That is, when exercising at faster speeds, the potential for producing power is greatest, and, when exercising at slower speeds, force production is greatest.

In a study conducted by Jhon E. Kovaleski et al. four different isokinetic training protocols were used and it was seen that when progressing from fast to slower speeds for both extension and flexion, performing the faster speeds early in the exercise trial generally produces a greater average power and the effect of fatigue is reduced.[24] Fatigue results in greater oxygen consumption which in turn causes more stress on cardiovascular system[25] and thus slower the post exercise recovery.

Result of the present study can also be supported by the results of other study done by Coyle et al which stated that there is enhancement of muscle power output by high-velocity training[26]. Also in another study it was seen that the slower speeds are performed under greater resistance than the faster speeds so that the muscle may fatigue more quickly when working at slower speed.[27] Therefore in protocol 1 when the slow velocity is given earlier, the HRR may take more time to come back to pre- exercise level.

So on basis of these results the faster HRR in protocol 2 which progressed from faster to slower velocity could be correlated with more power production and less fatigue as compared to protocol 1 which progressed from slower to faster velocity.

FUTURE STUDIES

Future studies can be carried out by assessing the effects of isokinetic protocols on older population and on those having some cardiopulmonary problems. Further studies on effect of different isokinetic training protocols during upper limb exercises on cardiovascular variables can also be carried out.

CONCLUSION

The present study was carried out to compare the effects of different isokinetic training protocols on cardiovascular variables in adult population. The result of present study concludes that different orders of velocities in isokinetic training will have different effect on cardiovascular variables. Protocol in which faster velocity was preceded by slower velocity (i.e. protocol 2) imposes less stress on cardiovascular variables.

REFERENCES

1. Karyn Solomon, Blood pressure and heart rate responses to a standard lower limb isokinetic test, Australian journal of physiotherapy 38:95-102,1992.
2. Dvir Z, Isokinetic Muscle Testing, Interpretation and Clinical Application, Churchill, Livingstone, 2004.
3. Muscolino J.E., kinesiology: The skeletal system and muscle function, Mosby Elsevier, St. Louis, 2006.
4. Davies G.J., A Compedium of isokinetics in clinical usage and rehabilitation techniques (4th ed) Onalaska, WI: S&S Publishers, Wisconsin, 1992.
5. Reichard L.B., Croisier J.L., Malnati M., Kartz Leurerm., Dvir Z., Testing knee extension and flexion strength at different range of motion: an isokinetic and electromyographic study, Eur J. Appl. Physiol., 2005, 95,371-376.
6. Martim Bottaro, Andre Faria Russo, Ricardo Jaco De Oliveira, The Effects of Rest Interval on Quadriceps Torque During an Isokinetic Testing Protocol in Elderly, J Sports Sci Med. 2005 Sep; 4(3): 285–290.
7. Victor L. Katch, William D. McArdle, Frank I. Katch.Essentials of exercise physiology.fourth edition pg. 453,456.
8. Su SW, Celler BG, Savkin AV, Nguyen HT, Cheng TM, Guo Y, Wang L.: Transient and steady state estimation of human oxygen uptake based on noninvasive portable sensor measurements. Med Biol Eng Comput. 2009 Oct;47(10):1111-7. doi: 10.1007/s11517-009-0534-0.
9. Fairbarn M, Blackie S, Mcelvaney N, Wiggs B, Pare P, Pardy R:. Prediction of heart rate and oxygen uptake during incremental and maximal exercise in healthy adults. chest 1994;105:13659
10. Su S, Wang L, Celler B, Ambikairajah E, Savkin A. : Estimation of walking energy expenditure by using support vector regression. Proceeding of 27th annual international conference of IEEE engeneering in medicine and biology society, 2005. Pp. 3526-9.
11. Astrand Po, Cuddy Te, Saltin B, Stenberg J. :Cardiac output during submaximal and maximal work. J Appl Physiol. 1964 Mar;19:268-74
12. Hill LK, Sollers Lii JJ, Thayer JF. Evaluation of a simple estimation method for the derivation of cardiac output from arterial blood pressure and heart rate. Biomed Sci Instrum. 2012;48:165-70
13. Pierpont GL, Stolpman DR, Gornick CC. Heart rate recovery post-exercise as an index of parasympathetic activity. J Auton Nerv Syst. 2000 May 12;80(3):169-74.
14. Maddox TM, Ross C, Ho PM, Masoudi FA, Magid D, Daugherty SL, Peterson P, Rumsfeld JS:The prognostic importance of abnormal heart rate recovery and chronotropic response amongexercise treadmill test patients. Am Heart J. 2008 Oct;156(4):736-44. doi: 10.1016/j.ahj.2008.05.025.
15. Yi Da Tang, Thomas A. Dewland, Detlef Wencker,, Stuart D. Katz.:Post-Exercise Heart Rate Recovery Independently Predicts Mortality Risk in Patients with Chronic Heart Failure. J Card Fail. Dec 2009; 15(10): 850–855.
16. Iellamo F, Legramante JM, Raimondi G, CastruccI F, Damiani C, Foti C, Peruzzi G, Caruso I:Effects of isokinetic, isotonic and isometric submaximal exercise on heart rate and blood pressure. Eur J Appl Physiol Occup Physiol. 1997;75(2):89-96.
17. Mark Loftin, Melinda Sothern, Barbara Warren, and John Udall :Comparison of VO2 Peak during Treadmill and Cycle Ergometry in Severely Overweight Youth, J Sports Sci Med. 2004 Dec 1;3(4):554-60. eCollection 2004.
18. Duvaliet A., Kouassi B.Y.L., Carzon J., Rieu M: Heart Rate During Functional Isokinetic Testing of Muscle;Iokinetic and exercise science vol. 3 no. 4 1993, pg 188-194.
19. Francis Degachea, Frederic Rocheb, Pierrick Bernardc And Paul Calmelsa: Cardiovascular responses during isokineticknee extension testing in chronic heart failure patients, Isokinetics and Exercise Science 17 (2009) 1–5.
20. Uchechukwu Dimkpa: post-exercise heart rate recovery: an index of cardiovascular fitness; journal of exercise physiology online Volume 12 Number 1 February 2009.
21. Christopher R. Cole., Eugene H. Blackstone, Fredric J. Pashkow, Claire E. Snader: Heart-Rate Recovery Immediately after Exercise as a Predictor of Mortality; N Engl J Med 1999; 341:1351-1357 October 28, 1999.
22. Okamoto T., Masuhara M., Ikuta K.: Cardiovascular responses induced during high-intensity eccentric and concentric isokinetics muscle contraction in healthy young adults; Clin. Physiol. Funct. Imaging, 2006, 26,39-44.
23. Na Du, Siqin Bai, Kazuo Oguri, Yoshihiro Kato, Ichie Matsumoto, Harumi Kawase, and Toshio Matsuoka: Heart Rate Recovery After Exercise and Neural Regulation of Heart Rate Variability in 30-40 Year Old Female Marathon Runners; J Sports Sci Med. 2005 Mar; 4(1): 9–17.
24. John E. Kovaleski, Rober J. Heitman, Frederick M.Scaffidi, Frank B. Fondren: Effect of isokinetic velocity spectrum exercise on average power and total work. Journal of athletic training.1992; 27(1) 54-56
25. W.L. Beaver, K. Wassermann and B.J. Whipp, A new methodfor detecting anaerobic threshold by gas exchange, J ApplPhysiol 60 (1986), 2020–2027.
26. Costell DF, Coyle EF, Fink WF, Lessman GR, Witzmann FA:Adaptation in skeletal muscle following strength training;J App Physiol.1978,46:96-99.
27. E.F. Coyle, D.C. Feiring, T.C. Rotkis , R.W. Cole, F.B. Roby, W. Lee, J.H. Wilhmore: Specificity of power improvement through slow and fast isokinetic training. J App Physiol. 1981;51:1437-1422.