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Original Article

Myocardial Oxygen Consumption and Perceived Exertion in Concentric Versus Eccentric Emphasised Exercise

Mayank Agarwal, Sunita Tiwari, Priyanka Sharma, Jagdish Narayan and Shraddha Singh*

Department of Physiology,
King George's Medical University,
UP, Lucknow

Abstract

Background: Dynamic muscle contraction comprises of a muscle-shortening phase known as 'concentric', and a muscle-lengthening phase known as 'eccentric'.

Aim: To compare the physical exertion assessed by Borg's rating of perceived exertion (RPE) 6-20 scale and rate pressure product (RPP) as an indicator of myocardial oxygen consumption in concentric emphasised exercise (CEE) with eccentric emphasised exercise (EEE).

Methods: In this non-randomised crossover study, twenty-five, apparently healthy, male adults, aged 18-25 years, having BMI 18-23 kg/m^2, performed moderate intensity CEE and EEE with dumbbells and a treadmill. Systolic blood pressure, diastolic blood pressure, heart rate, mean arterial pressure, RPP and RPE were analysed in the study.

Results: At same absolute workload, myocardial oxygen consumption and physical exertion were significantly less during EEE as compared to CEE.

Conclusion: Eccentric emphasised exercise can be an alternative to a conventional training regimen for individuals having a low tolerance to the exertion.

Introduction

Current global physical activity trends show that more than 30% of the adults are physically inactive (1). In 2010, World Health Organization (WHO) identified physical inactivity as the fourth leading risk factor for global mortality, which accounted for approximately 3.2 million preventable deaths (2). Consequently, promoting regular exercise became an integral component of current guidelines for health promotion and improvement of the quality of life (3).

"Feeling of exertion" is one of the most common problems that either prevents a person from exercising or leads to non-compliance towards the conventional exercise regimen (4, 5). Hence, developing innovative

***Corresponding author :**

Prof Shraddha Singh, Department of Physiology, King George's Medical University, UP, Lucknow, Ph.: 9415010703; Email: drshraddhasingh@yahoo.com.

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ways of exercising that must cause less physical exertion is necessary for better acceptance and adherence of the sedentary individuals to the training protocol. Newer approaches to exercise requires a review of muscle contraction physiology. When the muscle shortens as it exerts tension to move the bony lever, contraction is known as concentric. When muscle exerts tension while lengthening, it is called an eccentric contraction. In an isometric contraction, no apparent motion of the limb occurs, because the force generated by the muscle cannot overcome the external resistance (6).

Few previous studies reported that eccentric exercise causes less exertion as compared to concentric exercise (7-9). Most of the studies have utilised specialised machines like isokinetic dynamometers to isolate eccentric and concentric contractions during exercise (7-9). Isokinetic dynamometers are costly, not readily available to the mass population, and allow only one muscle group to be trained. Daily functional activities are a mixture of concentric and eccentric contractions. Hence, an exercise which emphasises on eccentric contractions rather than isolating them might be more beneficial in a full body workout. Furthermore, studies have focused on maximal intensity eccentric exercise for the development of muscle strength (7-9). Exercise performed at high-intensity increase the chances of cardiovascular complications in sedentary individuals (10). Also, high-intensity training has not demonstrated superiority over moderate intensity training in reducing cardiometabolic risk factors (11).

The rate pressure product (RPP) is a product of heart rate with systolic blood pressure. RPP is an index that best correlates with the relative myocardial oxygen consumption during exercise (12, 13). Borg's 6-20 scale ratings of perceived exertion (RPE) is a most common subjective method of gauging exercise intensity in adults. RPE is a psychophysiological approach that enables a person to rate on a numerical scale their exertion level relative to the cardiorespiratory, metabolic, and thermal stimuli perceived during exercise (14, 15).

At present, there is a gap in the feasible application of the eccentric exercise on a large scale. Therefore, the present study utilised an easily available and cost effective intervention in the form of a treadmill and dumbbells for constructing eccentric emphasised (EEE) and concentric emphasised exercise (CEE) training program. There is a paucity of data that compares physical exertion and myocardial oxygen consumption in eccentric exercise with concentric exercise performed at moderate intensity. Therefore, the present study was designed to compare RPP and RPE in moderate intensity CEE with EEE.

Materials and Methods

The present non-randomised crossover study was conducted in the Exercise Physiology Laboratory of King George's Medical University, UP, Lucknow, from August 2015 to September 2016, after approval by the Institutional Ethical Committee.

The sample size was calculated by the G*power software v3.1.9.2 (16, 17) on the basis of the results reported by a previous study, in which rate pressure product for young participants after concentric exercise was 209±46, while after eccentric exercise was 151±27 (8). At 80% power, 5% significance level, and 50% correlation between the groups, calculated sample size was 9 if two tailed paired t test or Wilcoxon signed ranks test is to be used. However, 25 subjects were enrolled in the present study.

Inclusion and exclusion criteria:

Apparently healthy, and young (aged 18-25 years) individuals with a normal body mass index (BMI) of 18-23 kg/m^2 [as per Asia Pacific guidelines of the World Health Organisation (18)] was involved in the study. All the participants had a sedentary lifestyle assessed by 'general practice physical activity questionnaire' (19). The exclusion criteria was the history of any disease or abnormality detected during the physical examination, which might have adversely affected the participant's health.

Training protocol:

Study was divided into two phases. During phase 1, all participants did concentric emphasised exercise. After a rest of 15 days, phase 2 was started in

which all participants did eccentric emphasised exercise. Training protocol was divided into (a) familiarisation cum training sessions and, (b) Last exercise session or test day, on which parameters were recorded.

a. Familiarisation Sessions.

Participants were instructed to refrain from strenuous muscular activity during the study period. All exercise sessions were done at the same time of the day (2 PM to 4 PM) to eliminate the effect of circadian rhythm. Participants were advised to wear non-restrictive and comfortable clothing during exercise.

Six familiarisation cum training sessions were conducted before the test day, to ensure maximal coordination of eccentric and concentric emphasised contractions and minimal muscle soreness. Each training session lasted for about 35 minutes, followed by 48 hours of rest. During these sessions, participants were made aware of the Borg's rating of perceived exertion, and they got accustomed to the exercise methodology.

1-Repetitive Maximum (1-RM) is defined as the maximum load that can be lifted once, while 10-RM is the maximum load that can be lifted ten times through a joint's full range of motion. 1-RM differs in trained and untrained individuals. Since amateur subjects were included in the study, 1-RM was calculated from 10-RM using the following equation: 1-RM (kg) = 1.554 × 10-RM weight (kg) – 5.181 (20).

The moderate intensity exercise was ensured by keeping the weight of the dumbbell at 60% of the 1-RM and adjusting the speed of the treadmill for each participant to keep their heart rate below 70% of the calculated HRmax. The maximum heart rate was determined by the formula proposed by Tanaka et al., HRmax = 208 – 0.7×Age (21). HR was monitored continuously during the exercise sessions by 'ChoiceMMed pulse oximeter MD300C20'.

The speed of the treadmill and 1-RM for an individual were determined during the concentric emphasised exercise phase and kept same for that individual during eccentric emphasised exercise phase so that absolute workload remains constant.

b. Test day.

On test day, participants walked on the 'Pro Bodyline Fitness Treadmill 970' for 15 minutes. A study predicted that the mechanical efficiencies of walking at +0.15 and -0.15 grade attained those of concentric and eccentric muscle contraction, respectively (22). Hence, for concentric emphasised exercise, treadmill having was inclined at +.16 grade (or 9° slope from horizontal); while for eccentric emphasised exercise, the treadmill was declined at -.16 grade (-9° slope) using a wooden wedge.

After a minute of rest, weight-lifting exercises by dumbbells was done for biceps, triceps, hamstrings and quadriceps muscles. Two sets of 12 repetitions were performed for each: 'dumbbell biceps curl', 'standing dumbbell triceps extension', 'dumbbell stiff legged dead lifts' and 'dumbbell squats'. A rest period of one minute was given between each set. During concentric emphasised exercise, participants were asked to count 'one' to 'five' slowly (corresponding to five seconds) while performing the full range of concentric motion, and count only 'one' (corresponding to one second) while performing the eccentric motion. Similarly, for eccentric emphasised exercise, an eccentric motion was about five seconds, whereas concentric motion was for one second.

Systolic blood pressure (SBP in mm Hg), diastolic blood pressure (DBP in mm Hg), heart rate (HR as beats/min), mean arterial blood pressure [MAP = DBP + $^1/_3$× (SBP-DBP) mm Hg] and rate pressure product [RPP=SBP*HR/100 in arbitrary units (AU)] was recorded/calculated just before and immediately after the exercise sessions by 'Omron HEM 7130-L' automatic blood pressure monitor. After the exercise session, participant's response to exertion level was registered on a form containing Borg's RPE (ratings of perceived exertion) 6-20 scale.

Statistical Analysis:

Primary data entry and calculations were done using an Excel database (Microsoft Office Excel 2016). All data were rounded off to nearest one decimal place. Further statistical analyses were performed using the software IBM SPSS Statistics v24.0 for Windows

(IBM Corp., Armonk, New York. Released 2016). Normality of data distribution was analysed by Shapiro-Wilk test. Means and standard deviations were reported in the descriptive analyses of quantitative data, while median with 25th and 75th interquartile were reported for ordinal data. For comparative statistics, paired samples t test or Wilcoxon signed ranks test (for ordinal data) was appropriately applied for within-group and in-between group data. P value <0.05 was considered significant.

Results

The mean age and body mass index (BMI) of participants were 20.5±1.8 years and 20.9±1.3 kg/m^2 respectively. No dropout was recorded during the study.

Table I represents that there was no significant difference in SBP, DBP, HR, MAP and RPP before concentric emphasised (CEE) and eccentric emphasised exercise (EEE). CEE resulted in significantly higher SBP, HR, MAP and RPP as compared to EEE, while there was no significant difference in DBP (Table II). The mean percentage change (percentage increase in variables from baseline) in SBP, HR, MAP and RPP were significantly higher after CEE as compared to EEE, while the percentage change in DBP was non-significant (Fig. 1).

TABLE I : Comparison of cardiovascular parameters before performing concentric and eccentric exercise.

Parameters n=25	*Pre concentric exercise*	*Pre eccentric exercise*	*P value**
SBP (mm Hg)	121.0±3.5	120.9±3.6	.700
DBP (mm Hg)	78.5±3.7	78.3±3.6	.284
HR (/min.)	76.0±5.0	76.0±5.2	1.000
MAP (mm Hg)	92.7±3.2	92.5±3.2	.351
RPP (AU†)	92.0±7.1	92.0±7.5	.859

Data expressed as mean±SD. *paired t-test, †arbitrary unit, P value <.05 is significant.

TABLE II : Comparison of cardiovascular parameters after concentric and eccentric exercise.

Parameters n=25	*Post concentric exercise*	*Post eccentric exercise*	*P value**
SBP (mm Hg)	139.2±3.7	133.6±3.2	.0001
DBP(mm Hg)	81.3±4.6	81.1±4.3	0.526
HR (/min.)	133.5±8.3	124.2±10.5	.0001
MAP(mm Hg)	100.6±3.4	98.6±3.3	.0001
RPP (AU†)	185.9±14.4	166.1±15.9	.0001

Data expressed as mean±SD. *paired t-test, †arbitrary unit, P value <.05 is significant.

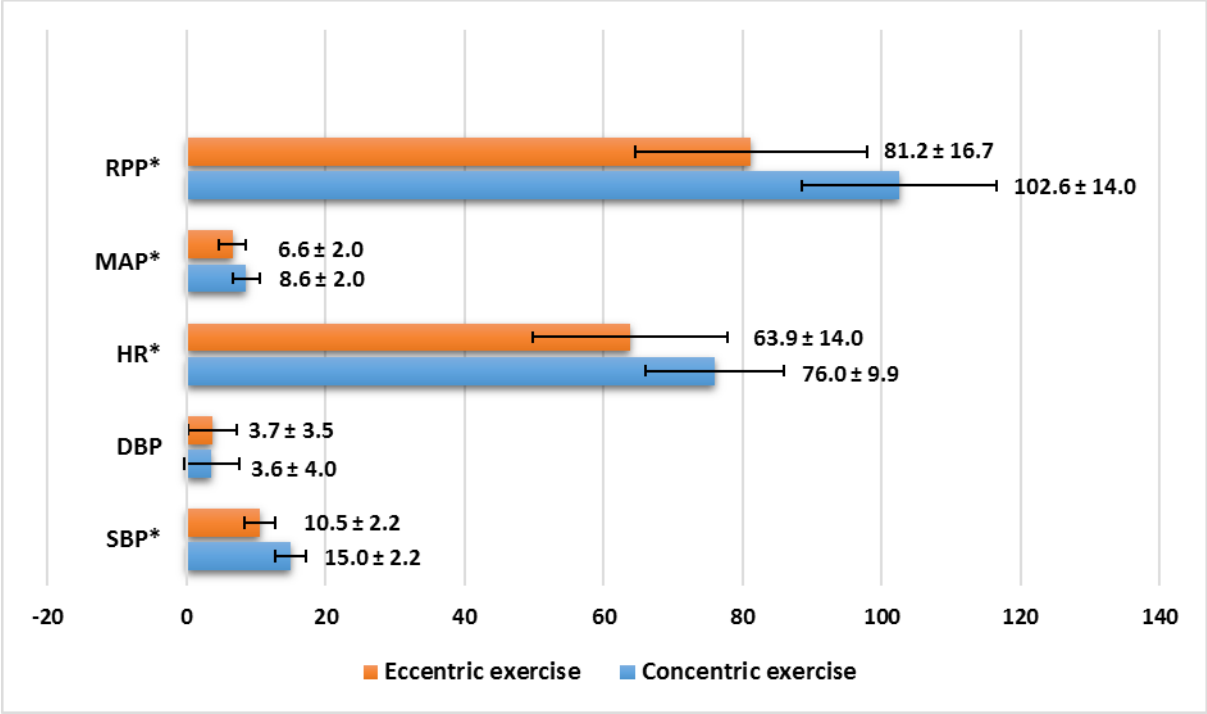

Fig. 1 : Percentage change in cardiovascular variables after concentric and eccentric exercise.

RPE is an ordinal data, hence in the descriptive analyses median with 25th and 75th quartiles were reported (Table III). For comparative analysis, the non-parametric counterpart of paired t test, i.e., Wilcoxon signed ranks test was used. At same absolute workload, RPE was significantly higher for concentric as compared to eccentric exercise (Table-III).

TABLE III : Comparison of ratings of perceived exertion (RPE) after concentric and eccentric exercise.

Parameters n=25	*Post concentric exercise*			*Post eccentric exercise*			*P value**
	Median	*25th per-centile*	*75th per-centile*	*Median*	*25th per-centile*	*75th per-centile*	
RPE	13.0	11.5	13.0	11.0	10.0	13.0	.0001

*Wilcoxon signed-ranks test, P value <.05 is significant

*P value = .0001 for paired t test.

Discussion

The results of the present study showed a significant higher RPE, RPP, SBP, MAP and HR in response to moderate intensity concentric emphasised exercise, as compared to eccentric emphasised exercise at the same absolute workload.

It is difficult to compare the results of the present study with previous ones, due to wide variation in exercise protocol, measurement techniques, and subject characteristics. Still, the cardiovascular response obtained in the present study is in close agreement with the results from Overend et al., who reported lesser HR, SBP and MAP response to 2 minutes of eccentric exercise bout performed on an isokinetic dynamometer for knee extension, as compared to concentric exercise (8). However, Bhavna et al. reported a non-significant difference in HR and RPP response to concentric and eccentric exercise performed in four major muscle groups (23), which might be due to the small sample size (10 males) of their study. A significant lower RPE response to eccentric exercise obtained in the present study is in accordance with the results reported by Hollander et al., who have involved exercise-trained males in their study (24).

A recent study by Vincent et al. reported significant higher HR as well as RPE in maximal intensity eccentric exercise as compared to concentric exercise, performed on a novel machine designed by them (25). Maximal intensity eccentric contractions are known to cause more muscle damage resulting in pain (26), which could have resulted in higher RPE. Cardiovascular response to exercise depends on the muscle activity and metabolism, which is detected by muscle's mechanoreceptors and metaboreceptors respectively (27). Maximal intensity eccentric exercise might have caused more stimulation of these receptors as compared to concentric exercise, resulting in higher HR in eccentric exercise.

In the present study, the HR response to exercise was accentuated as compared to SBP, which can be explained by 'cardiovascular drift' phenomenon. Exercise performed for a long duration in high ambient temperature causes increased sweating resulting in a fluid shift from plasma to the tissues and redistribution of blood to the periphery for body cooling. The fluid shift and peripheral vasodilation results in reduced venous return. A reduced stroke volume due to decreased venous return initiates a compensatory heart rate increase to maintain a nearly constant cardiac output (20). India is a tropical country, thus has a high ambient temperature, which resulted in heightened HR response to exercise in the present study. In contrast with the rise in SPB, DBP was not changed substantially due to decrease in total peripheral resistance of the vessels within the exercising muscles by the release of local vasodilators, a phenomenon called 'sympatholysis' (28).

It has been postulated that eccentric contractions create more force than concentric contractions due to a greater distance covered by actin-myosin cross bridges (29). Eccentric contractions cause non-ATP-dependent mechanical rupture of actin-myosin cross bridges (29), which results in less energy utilisation and lesser stimulation of muscle's metaboreceptors. Thus, the work-done and energy expended would be less in eccentric exercise compared to concentric exercise. The lesser recruitment and discharge rate of motor units during eccentric contractions compared to concentric contractions (30) performed with a

similar absolute external load is consistent with the low RPP and RPE, observed in moderate intensity eccentric emphasised exercise done by young sedentary individuals involved in the present study.

Limitation of the study:

The present study involved young, healthy individuals; hence the results cannot be generalised to the overall population. Further studies are required to compare concentric with eccentric emphasised exercise training at submaximal intensities in debilitated individuals or those having cardiopulmonary limitations due to chronic lung and heart disease.

Conclusion

Individuals having a low tolerance to exertion may show better compliance towards the eccentric emphasised exercise training that can be performed easily by using a treadmill and dumbbells. Future studies should work on developing more innovative ways of exercising with a goal to maximally improve physical well-being with minimal exertion.

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