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Effects of 12-Week Rowing Training on Resting Cardiac Output, Stroke Volume, and Heart Rate of Stroke Survivors

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ABSTRACT

Rowing exercise is one of the cardiorespiratory exercises that induce higher aerobic capacity. Cardiorespiratory parameters, cardiac output (CO), stroke volume (SV), and heart rate (HR) are indicators to measure one's cardiorespiratory fitness. The aim was to study the effects of 12-week rowing training on resting cardiac output (RCO), resting stroke volume (RSV), and resting heart rate (RHR) of stroke survivors. Ten stroke survivors (6 males; 4 females), mean age of 43.6 ± 16.15 years, were subjected to a 12-week rowing training (Concept II Rowing Ergometer, Model C, USA). An individualised programme was prescribed based on %HRR for each of stroke individual. Rowing training was conducted twice per week (12 HIIT; 12 MR). Paired t-test and repeated measures ANOVA (RPM ANOVA) were used for statistical analyses using IBM® SPSS® Statistics 20 software. RPM ANOVA analysis showed no significant effect on RCO [F (5, 45) = 1.066, p = 0.392, RSV [F (2.188, 19.693) = 0.677, p = 0.532)], and RHR [F (5, 45) = 0.856, p = 0.518]. Paired t-test showed no significant difference between pre- and post-test despite the improved values of Mean ± Standard Deviation (RCO: 8129.50 ± 3916.31 to 8494.18 ± 6248.86 mL/min; RSV: 99.27 ± 33.98 to 121.84 ± 66.24 mL; RHR: 78.02 ± 17.39 to 77.17 ± 11.98 bpm) for all respective parameters. Twelve weeks rowing training did not improve resting cardiorespiratory parameters of stroke survivors statistically. Future studies are suggested to include gender difference and medication effect variables.

INTRODUCTION

Stroke is the second cause of mortality worldwide and is the third in developed countries following heart attacks and all cancers combined[1]. In Malaysia, stroke remains the third cause of mortality following ischaemic heart diseases as first and pneumonia as second[2, 3]. Individuals after stroke invariably show various types of post-stroke impairments in which one of them is cardiorespiratory fitness. A very low cardiorespiratory fitness is well established among stroke survivors[4, 5]. Over three quarters of stroke survivors have been estimated to have low levels of physical activity[6] and they spend most of their time in sedentary behaviours that contribute to low cardiorespiratory fitness[7]. Such low physical and sedentary behaviours reduce their ability to perform activities of daily living and also may contribute to a heightened risk of recurrent stroke and other cardiometabolic diseases[8].

Cardiorespiratory fitness is defined as the ability of the circulatory and respiratory systems (the heart, the lungs, and the blood vessels) having central capacity to supply oxygen to be utilized by the peripheral skeletal muscles especially the exercising muscles in an amount that is sufficient enough to meet the demands of the workload and prolonged physical activity[9, 10]. Cardiorespiratory fitness is frequently used interchangeably with terms such as aerobic fitness, cardiorespiratory endurance, cardiovascular fitness and maximal oxygen consumption[9, 11] and is associated with the ability to execute and tolerate a physical activity in continuous mode[10].

The best quantitative measure and most valid to measure functional capacity of cardiorespiratory system is maximal oxygen uptake (VO_2max)[12, 13]. VO_2max is the product of cardiac output and arteriovenous oxygen difference (AO_2 – VO_2 diff)[14] VO_2max (derived from V, volume per time; O_2, oxygen; max, maximum) also known as maximal oxygen consumption or aerobic capacity[13] the rate of oxygen uptake during performance of maximal exercise which reflects the circulatory and respiratory systems to deliver oxygen to working muscles that involves a large part of total muscle mass. Arteriovenous oxygen difference is the difference in the oxygen content of blood between arterial and venous blood, which indicates of how much oxygen is removed from blood capillaries as the blood circulates in one circulation through the systemic system[15]. The VO_2max as criterion measure of cardiorespiratory fitness is widely accepted and used[12].

Stroke volume (SV) and heart rate (HR) are the two major determinants in assessing cardiorespiratory fitness in accordance with VO_2max. The two major determinants are referred as cardiac output (CO)[16]. CO is the amount of blood that is pumped into the aorta by the heart per minute basis[17]. The CO (litres/min) is the product of SV (mL/beats) and HR (beats/min)[18]. The SV is the amount of blood that is ejected from a ventricle of the heart with each heartbeat. An increase in SV may increase the CO. The SV is determined by the preload (degree of ventricular filling when the heart is relaxed), afterload (pressure or resistance against which the ventricle must pump to eject blood), and contractility (contractile state of myocardium). The HR refers to the number of times the heart beats per minute and an increase in the HR may also increase the CO. Factors that affect HR are increased sympathetic activity, concentration of extracellular ions, hormone levels, medication, stress, anxiety, fear, and body temperature[17].

Cardiorespiratory exercise (aerobic exercise) is any type of activity which involves a large group of muscles that can be performed in continuous, rhythmic, and prolonged fashion[15] that lasts a minimum of 3 to 5 continuous minutes[9]. It is characterized by employing the large muscle groups of lower extremities in instances of walking, running, and cycling. Sometimes, it combines with the upper extremities like rowing and swimming[19]. Performing cardiorespiratory exercise can acquire a higher maximal oxygen uptake (VO_2max). An amount of oxygen that is utilized during the cardiorespiratory exercise will increase significantly and thus allows individual to exercise for a longer period and more intensely prior to becoming fatigued[20].

Indoor rowing exercise using rowing machine (indoor rower) challenges both the upper and lower body musculature which places higher demands on cardiorespiratory fitness compared to exercise that relies merely on either upper or lower body musculature[21]. Rowing exercise provides a complete body workout that mobilizes all of the major muscle groups, including those in the legs, arms, hips abdominals, trunk, shoulders, and back[22, 23]. Exercise using indoor rower is smooth and low-impact, which can improve and maintain flexibility of joints especially those with joint pain or limited mobility[22]. Rowing is one of the types of cardiorespiratory or aerobic exercise that has the nature of constant pushing and pulling against resistance activity. Workloads also can be regulated on most rowing machines to accommodate different fitness levels[23].

In this research, stroke survivors were subjected to rowing exercise training to study the effect of such training on cardiorespiratory parameters, which resting cardiac output (RCO), resting stroke volume (RSV), and resting heart rate (RHR). These three parameters were evaluated to determine cardiorespiratory fitness of stroke survivors.

MATERIALS AND METHODS

This study was conducted using quasi-experimental research design with time-series setting. Ethical approval was obtained and granted from Medical Research and Ethics Committee (MREC), NMRR-16-38-28777 (IIR), Ministry of Health Malaysia. All participants in this study were subjected to intervention programme of 12 weeks. Rowing training was performed twice per week that consisted of High-Intensity Interval Training (HIIT) and Moderate Rowing (MR). Total of 12 sessions for each HIIT and MR were successfully carried out by all the participants.

The study population involved 10 stroke survivors (6 males; 4 females), ranging between 16 to 63 years old. Mean age of 43.6 ± 16.15 years. All subjects were recruited from the Rehabilitation Specialist Clinic in Queen Elizabeth Hospital I, Kota Kinabalu, Sabah in which they were volunteered to participate in this study. Ten subjects were selected according to the exclusion and inclusion criteria. After having a clearance from their physician, all subjects underwent a baseline test and the written informed consent was taken soon after. All the patients involved in this study must be able to communicate and understand instructions given, possesses unilateral hemiparesis either left or right, medically stable (released by physician), able to walk with or without assistance, able to sit or stand with or without assistance, and able to transfer from a higher to lower position, chair to rowing seat (or vice versa) with or without assistance. In the other hand, patient with comorbidities, serious medical condition (bronchial asthma, heart failure, severe hypertension), elbow flexor contracture, plantar flexor contracture, and inability to bend knee (hamstring spasticity) and elbow (biceps spasticity) would be excluded.

Experimental Protocol

After baseline test was conducted, each patient was required to perform a one-minute rowing screen test to determine their rowing speed and abilities. According to their rowing's stroke per minute (SPM), the patients were divided into three groups. The three groups were low (< 18 SPM), moderate (18 – 23 SPM), and high (>24 SPM). The patients were subjected to perform rowing training twice a week, which consisted of high intensity interval training (HIIT) and moderate rowing (MR) for 12 weeks consecutively.

This study employed an electrical bioimpedance invasive technique that used Biopac Student Lab system (BIOPAC® System, Inc.) to measure RCO, RSV, and RHR of the stroke patients for one minute. Mean values of the RCO, RSV, and RHR for all patients were chosen within the timeframe of last 10 to 15 seconds of the one minute of their resting data. Measurement of RCO, RSV, and RHR were conducted at pre-test: week 0 (Test 1), post-$test_1$: week 3 (Test 2), post-$test_2$: week 6 (Test 3), post-$test_3$: week 9 (Test 4), post-$test_4$: week 12 (Test 5), and post-$test_5$: week 15 (Test 6).

Static stretching was performed by the patients before rowing training and cooling down after the training. Blood pressure monitor (OMRON, IA2, Japan) and oxygen level pulse oximeter JPD-500A, (Jumper, China), readings were taken before and after training. Patients wore a heart rate monitor (Suunto, M5) during rowing to monitor their HR. Correct breathing techniques were also taught to patients to prevent Valsalva *manoeuvre* during rowing. For patients with spastic lower limbs, custom-made strap was used to align the limbs' movement and bandage was used to secure handgrip during rowing.

Rowing Mode and Intensity

The main purpose of this study was to use rowing as rehabilitation tool for people with disabilities. A rowing screen test performed by all patients in one minute. The objective was to categorise them into three groups of rowing speed and abilities baseline as described in the experimental protocol. The rowing training was carried out by patients afterwards.

Principle of percentage of heart rate reserve (HRR) was applied to prescribe the patients' training intensity. The formula, THR (target heart rate) = HRR (percentage of intensity) (%) × [HR_{max} – RHR] + RHR was used to calculate training intensity of each patient, where HR_{max} was referred to maximal heart rate and RHR was resting heart rate. As stroke survivors suffered with poor cardiovascular endurance as in the elderly, %HRR is more accurate than %HRmax[24].

Patients with low rowing ability (<18 SPM) started at 50% of heart rate reserve (HRR); patients with moderate rowing ability (18 – 23 SPM) at 55%; and high rowing ability group (≥24 SPM) at 60% of HRR. Rowing training was carried out twice per week with HIIT and MR which were performed consecutively. Progressive load increment was applied throughout the 12-week of rowing training in terms of working time (speed on rowing ergometer), distance covered, and damper setting.

For HIIT rowing session, it was started with a ratio of 1:1 (working: recovery) of 15:15 seconds, and progressively increased to 20:20, 25:25, 30:30, and 35:35 consecutively. Percentage of HRR was measured individually, where each patient was instructed to row at maximal effort (to achieve THR). For MR rowing session, it was started with a 500 meters rowing and progressive increment of 50 meters or more (minimum) was performed according to their %HRR. The increment would be based on patients' effort which in regard to their THR and MBDS (Modified Borg Dyspnoea Scale).

However, it would be depending on the patient's ability to achieve THR during each training session. A subjective scale, MBDS was shown to the patient after each repetition to acknowledge their level of tiredness. All patients were ensured that they would be free from symptoms-limited exercise testing as provided in the American Council of Sports Medicine's guidelines.

Statistical Analyses

Data were analysed using IBM® SPSS® Statistics 20 software. Repeated measure ANOVA was used to test the significant difference of RCO, RSV, and RHR value in six different tests. Paired sample *t*-test was used to determine the differences from pre-test to post-test of RCO, RSV, and RHR. The alpha level was set at $p<0.05$.

RESULTS

This study used a repeated measures design in which ten patients with their exercise prescription that was designed specifically for each of them focusing on their cardiorespiratory endurance for twelve consecutive weeks with a rowing ergometer aid. Mauchly's Sphericity principle had been violated and therefore correction was made using Greenhouse-Geisser (except RSV) correction.

RPM ANOVA (Table 1) analysis showed that the rowing training had no significant effect on RCO [F (5, 45) = 1.066, p = 0.392, RSV [F (2.188, 19.693) = 0.677, p = 0.532)], and RHR [F (5, 45) = 0.856, p = 0.518]. Paired t-test also showed that there was no significant difference between pre- and post-test (Table 2).

Table 1 RPM ANOVA OF RCO, RSV, and RHR

Variables	Wk0	Wk3	Wk6	Wk9	Wk12	Wk15	Repeated Measures ANOVA (RPM ANOVA)		
							Main Effect (t)		
	Mean ± SD						df	*F*	*p*
RCO	8129.50± 3916.31	8638.30± 4309.20	10248.90± 6322.37	11667.30± 8706.93	9133.90± 4986.67	8494.18± 6248.86	5.00	1.066	0.392
RSV	99.27± 33.98	117.48± 57.11	125.30± 83.87	140.95± 91.18	113.51± 59.29	121.84± 66.24	2.188	0.677	0.532
RHR	78.02± 13.53	73.62± 13.53	83.40± 21.39	79.69± 12.87	81.24± 18.16	77.17± 11.98	5.00	0.856	0.518

Significant value set at $p<0.05$

Table 2 Paired t-test of variables

Variables	Mean ± Standard Deviation		*r*	*t*-test	*p*-value
	Pre-test	Post-test$_6$			
RCO	8129.50 ± 3916.31	8494.18 ± 6248.86	0.514	-0.213	0.836
RSV	99.27 ± 33.98	121.84 ± 66.24	0.255	-1.077	0.310
RHR	78.02 ± 17.39	77.17 ± 11.98	0.226	0.140	0.892

Significant value set at $p<0.05$

However, Mean ± Standard Deviation value of RCO was increased from pre to post-test$_6$ (Figure 1), which indicated improvement in efficiency of the heart though there was a downhill in the fifth test. RSV value increased steadily (Figure 2), showed that the heart might have ejected more blood in one beat. There was a drop in fifth test however RSV value still recorded an improvement from pre to post test. RHR value was inconsistent throughout the tests. In post test$_6$, RHR was reduced (Figure 3), suggested that the heart was capable of providing a sufficient amount of blood in a lower beat. Mean differences for RCO, RSV, and RHR were −364.68, −22.57, and −0.85 respectively.

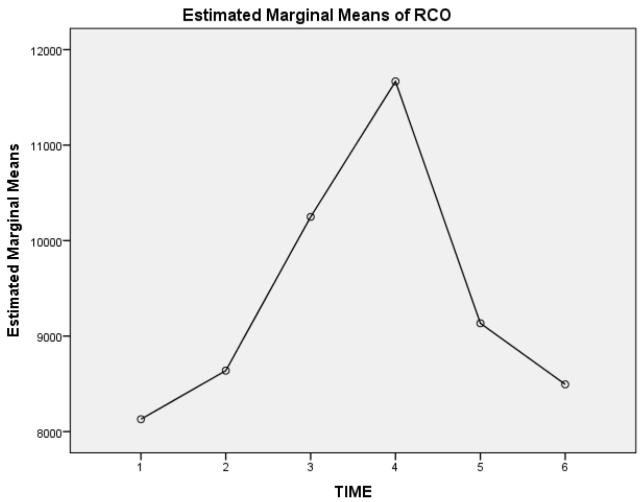

Figure 1 Data of RCO for all six tests throughout 12 weeks of rowing training showed RCO improved from Test 1 to Test 4, it dropped in Test 5 and showed improvement in Test 6.

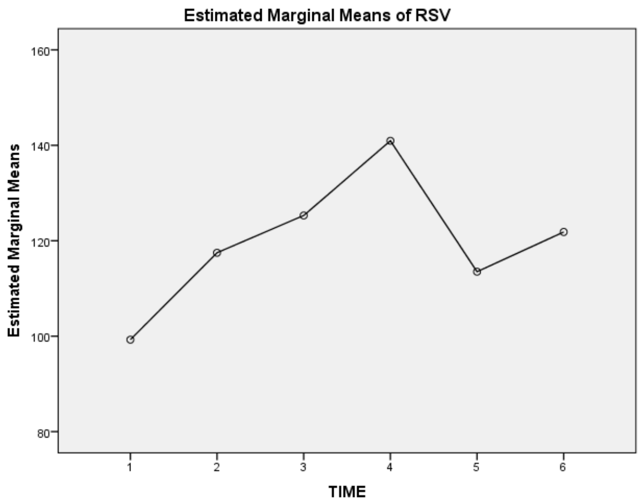

Figure 2 Data of RSV for all six tests throughout 12 weeks of rowing training showed RSV improved steadily from Test 1 to Test 4, declined in Test 5 and showed improvement in Test 6.

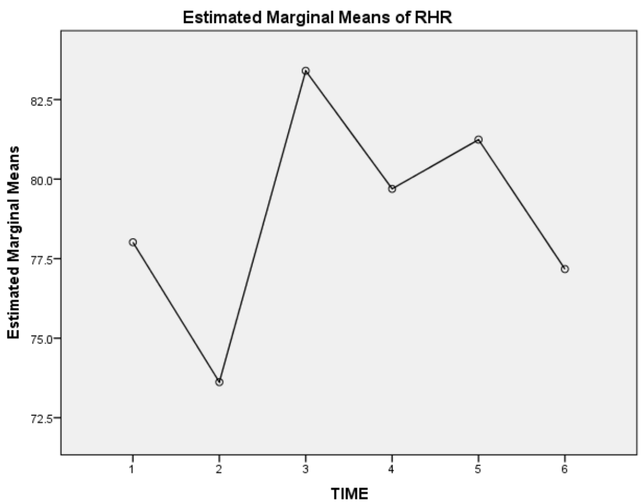

Figure 3 Data of RHR for all six tests throughout 12 weeks of rowing training showed inconsistent reading of RHR, however in Test 6 showed a reduction value from Test 1.

DISCUSSION

The results showed that the 12-week rowing training had no significant effect on cardiorespiratory fitness parameters among the stroke survivors. However, Mean ± Standard Deviation of RCO, RSV, and RHR values showed improvement.

Rowing was found to prevent cardiovascular deconditioning of people with 5-week bed rest condition[25] due to its kinematic pattern exercise and low impact, which their cardiorespiratory parameters were measured during exercise. However, in our study the cardiorespiratory parameters during resting (upright sitting position) state were measured. There was still lack of studies regarding the effect of aerobic exercise on RCO, RSV, and RHR on a resting condition.

During upright exercise, oxygen demands were increased, which required the CO to increase to deliver more blood to the working muscles, therefore HR was increased, and SV was reduced to compensate the HR[26]. Nonetheless in this study, according to Frank-Starling mechanism, increased in plasma volume and venous return contributed to the increased in end-diastolic volume or preload after endurance training programme[27]. To support the result in this study, reduced Mean ± Standard Deviation value of RHR might be due to enhanced vagal tone[27] after 12 weeks of rowing training. Despite, HR would be a less accurate measurement for people who were taking beta-blockers[28], therefore MBDS was used in this study to support the result. In this study, types of beta-blockers taken by the stroke survivors were not discerned as they were not included in research parameters.

A marked increased in CO was proven after isotonic exercises[29]. The increased in maximal CO was largely contributed by increased in SV. There were three factors that contribute in increasing SV, (1) Preload, (2) Afterload, and (3) Inotrophy. RSV measurement was taken in this study under resting condition, SV was mostly dependent on ventricular filling pressure which was the venous return[30, 31]. Higher RSV also indicated greater fitness level[32] thus this showed that increased Mean ± Standard Deviation value of RSV had proven that rowing induced greater aerobic capacity of the stroke survivors. Fick equation proved that there was a positive linear relationship between VO_2max and CO[33, 34]. There was a study proved that resting or exercise CO was improved after 12 weeks of HIIT[34]. The increased Mean ± Standard Deviation value of RCO showed that rowing training improved cardiorespiratory parameters within stroke patients.

LIMITATIONS

Limitation in this study was that the sample was too small to represent a population. More subjects should be recruited in future study to apprehend the significant effects of rowing on cardiorespiratory parameters of this population. In addition, types of medication consumed by the patients were not taken into account. People with stroke who consumed drugs that contained beta-blockers might affect the changes in their HR that would have an effect on RSV and thus influenced RCO. As a consequence, the result of this study was not statistically significant although Mean ± Standard values were improved.

CONCLUSION

Rowing movement engages more gross muscles contractility when compared to other exercises. More motor units are needed to be activated and thus result in higher energy expenditure within the stroke patients. In this study, although there was no statistically significant effect on RCO, RSV, and RHR after 12-week of rowing training based on the results, yet there was improvement in all of the variables of the stroke survivors. Future studies should consider on types of medication consumed by the stroke patients and its peak effect on HR, SV, and CO. Also there is a need to increase the sample size to withstand the statistic tests.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests in publishing this paper.

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