ORIGINAL ARTICLE

Comparison the acute effect of moderate-intensity treadmill exercise and arm crank exercise on autonomic cardiac functions in adult males

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Abstract

Background and Study Aim: Cardiovascular parameters testing can be used by various modalities ranging from ground running to sophisticated computerized treadmills. The purpose of this study was to compare the acute effect of treadmill moderate-intensity exercise with arm crank exercise on autonomic cardiac function among adult males.

Material and Methods: One hundred-twenty male participants participated in this study. They were randomly allocated to a treadmill exercise group with sixty participants and the other sixty participants allocated into an arm crank exercise group. Both groups performed exercises for forty minutes. Autonomic cardiac functions (heart rate variability - HRV), heartbeats, and arterial blood pressure) were determined with the help of Phillips DigiTrak XT Holter heart rate monitor, Polar® Grit X watch, and automatic sphygmomanometer. An independent t-test was used to compare the anthropometric data between both groups. Repeated measure analysis of variance and one way analysis of variance (ANOVA) were used to determine the differences between treadmill exercise and arm crank for autonomic cardiac functions among adult males.

Results: The HRV decreased significantly during treadmill exercise and arm crank exercise. Mean values of heartbeats (HR), systolic blood pressure (SBP), and rate pressure product (RPP) increased significantly during both exercises. In comparison, mean values of HRV parameters were reduced more significantly during treadmill exercise than arm crank. Mean values of the HR, SBP, and RPP increased significantly during arm crank than treadmill exercises.

Conclusions: The study's findings suggest that treadmill exercises are responsible for a greater significant reduction in HRV. The HR, SBP, PP, and RPP significantly increased during arm crank than treadmill exercises. This study suggests that when recommending exercise to adult male individuals, the intensity and mode of exercise are crucial.

Keywords: arm crank, treadmill, leg exercise, acute exercise, moderate-intensity, physiological responses.

Introduction

Exercise is essential in preventing and maintaining health in all age groups [1, 2]. Exercise promotes controlling body weight, reducing body fat, reducing the risk of cardiac diseases, managing blood sugar and insulin levels, and improving cardiorespiratory fitness [3]. Despite the benefits of regular exercises in preventing and treating different types of patients during the rehabilitation process or training purposes, if it is not prescribed and supervised properly, it might raise the relative risk of musculoskeletal injury or cardiovascular events [4]. As a result, attention should be taken while performing exercise for rehabilitation purposes. Due to the above purpose, a trainer or a physical therapist should better understand the biological individuality through tests to measure physical capacity. The prescription and supervision are appropriate for a safe workout [5].

Several studies have shown that repeated intermittent treadmill exercise is an effective therapeutic strategy [6]. Treadmill exercise provides a significant benefit over other types of exercise. The volume of external work done can be easily determined, and exercise intensity and duration can be regulated [7]. Observational studies conducted in the 1980s and early 1990s determined the treadmill exercise test for prognostic importance. Treadmill exercises were used to determine the maximal exercise capacity, whether evaluated by exercise

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time or workload accomplished. Treadmill exercise test data have confirmed that heart rate recovery is a marker of physical fitness and exercise capacity, irregular heart rate recovery is a major predictor of mortality in the cardiac patient [8], asymptomatic individuals [9], and exercise training improves heart rate recovery in cardiac patients [10].

Arguments have been made in the past that the specificity of the testing procedure affects the performance of parameters during testing. Different protocols have investigated the physiological differences between arm and leg exercises. Arm crank is a useful substitute to a treadmill for exercise [11]. The exercise protocol is graded in the same way as a treadmill protocol is, with two-minute increments in effort until exhaustion. Peak heart rate is 90 to 95 percent of what is expected on the treadmill, and peak systolic blood pressure is 80 to 85 percent of what is expected. As a result, the double product is often high enough to reveal ischemia alterations [12]. Apart from the importance of tests of upper body exercise capacity in athletes who use the upper body, such as swimmers and boaters, it is also an important measure for people who are unable to perform lower body exercises and can be a useful exercise tool for people with vascular diseases, orthopaedics and neurosurgery [13].

The treadmill is commonly used to improve cardiopulmonary fitness [14]. Arm crank is also used to improve health status for individuals who cannot use a leg bicycle or treadmill [15]. As a result, the location and size of the involved active muscle during treadmill and arm crank exercise are different. They may have various cardiovascular effects that need to be investigated [16]. The interaction of the sympathetic and parasympathetic over the heart during exercise is worthy of being investigated, and it has been an interesting research point [17, 18]. Most of the previous studies have focused on evaluating the cardiovascular effect upon upper or lower limb exercise [16]. There is no available data that compared the effect of the treadmill and arm crank exercise on autonomic cardiac functions, except one study compared the effect of arm crank with leg cycle ergometer in middle-aged individuals [15]. Therefore, the aim was to compare the acute effect of treadmill moderate-intensity exercise with arm crank on autonomic cardiac function in the normal adult. It was null hypothesized that there is no significant difference between treadmill moderate-intensity and acute arm crank exercise on autonomic cardiac function in normal adults.

Materials & Methods

Participants

One hundred-twenty adult males' participants participated in this study. Sixty participants were randomly assigned to the treadmill exercise group and sixty to the arm crank exercise group.

Inclusion criteria: non-obese male volunteers with body mass index < 30 kg/m^2, aged from 25-36 years. All participants were asymptomatic for cardiovascular and respiratory diseases. They currently do not receive any medical prescriptions.

Exclusion criteria: Any participant with a history of cardiovascular or pulmonary diseases or has taken any medicine that may affect their performance during the test [15].

Ethical approval. This study was approved by the Ethics Research Committee of the Institutional Review Board of Imam Abdulrahman Bin Faisal University (IRB-2015-03-159). Before participating in this study, each participant signed a consent form and was informed that collected data would only be used for research purposes.

Study Design

Comparative cross-sectional design was selected to conduct this study.

Assessment procedure: Every participant was asked to avoid strenuous exercise, caffeine beverages, and have enough rest for two days before the test session to avoid any carry-over effect of stimulants or depressants on autonomic function [15, 18]. Every participant underwent the following assessment.

Bodyweight and body mass index were measured with auto calibrated stadio scale.

Heart rate variation was measured using the Philips DigiTrak XT-Holter heart rate monitor, a highly validated method for detecting HRV measures [19]. The electrodes were attached to each participant's chest to detect HRV recordings before and during the exercise session. The recorded data of time domains were transferred to a computer for further analysis.

Arterial blood pressure: Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured by using an electronic sphygmomanometer (Geratherm, Germany) [20]. Mean arterial blood pressure (MABP) is the perfusion pressure of the body organs; normally, it ranges from 65 to 110 mmHg [20]. It was calculated as [DBP + 1/3 pulse pressure] [20]. Pulse pressure (pp) = SBP - DBP. The rate pressure product (RPP) is an indirect method that easily measurable the index of myocardial oxygen consumption. It was calculated by multiplying SBP in mm Hg x HR in beats/min x 10^{-2} [20, 21, 22].

Exercise program: Before exposing the pre-intervention measures, every participant relaxed in a sitting position for 30 minutes to achieve hemodynamic stability. The heart rate monitor recorded continuous heartbeats at rest for 40 minutes and during exercise sessions for 40 minutes. The exercise intensity was determined in advance for every participant from 64 -74% of the

maximal heart rate (HR-max) [18, 22, 23]. The HR-max was calculated using the Karvonen equation (HRmax = 220-age) as it showed good correlations with the measured HR-max [24]. The recorded data were transferred from the device to the computer for further analysis.

Treadmill Group: Each participant performed exercise for 40 minutes on a computerized treadmill machine [15, 18]. Participant began at the lowest speed for 5 minutes at zero inclination as a warmup; then the speed was gradually increased to achieve the pre-determined individualized moderate intensity for 30 minutes, then exercise was continued to the slowest speed for 5 minutes for a cool-down exercise. The HR and blood pressure were recorded pre, during, and immediately after exercise.

Arm-crank Group: Each participant performed an arm crank exercise for 40 minutes with the Hudson machine from the sitting position. Seat's height and distance were adjusted to achieve full extension of participant arms at the horizontal (shoulder-level) position. For Warmup, each participant equally peddled with both arms on arm crank at the lowest speed for 5 minutes. The exercise intensity gradually increased to achieve individualized moderate intensity for 30 minutes. Each participant continued arm exercise at the slowest speed for 5 minutes for a cool-down exercise [15, 18]. The HR and blood pressure were recorded pre, during, and immediately after exercise.

Statistical analysis

The collected data were statistically analyzed using SPSS (Version 23.0) for descriptive and inferential analysis. The missing data, out lairs, and normality was checked and found that data were normally distributed. Parametric tests were used to analyze data. An independent t-test was used to compare the demographic data of both groups. The repeated measure analysis and one way analysis of variance (ANOVA) were used to determine the differences between treadmill and arm crank exercise for cardiac autonomic functions. Statistical significance was determined at p-value < 0.05 and confidence interval at 95%.

Results

Demographic data of participants

The mean values of age, body mass index, maximal HR and HRV maximal HR were (25.09±2.12, 24.94±2.32), (30.53± 4.93, 30.67± 5.41), (63.22±13.87, 63.69 ±13.29), and (189.52± 4.96, 189.33±5.40) of treadmill and arm crank groups respectively. Independent t-test showed non-significant differences between both groups p-value > 0.05.

On comparison of arm crank with treadmill exercises the mean values of both SDANN, SDNN and RMSSD of HRV showed significant differences (F-values =8.568,6.831&6.230) p-value = (0.004,0.010& 0.014) respectively with more reductions in HRV during treadmill than during arm crank exercises.

The one-way ANOVA (Table 1) showed significant reductions in mean values of the HRV (SDANN, SDNN, RMSSD) during both treadmill and arm crank exercises at 0.05 level of significance.

The repeated measure analysis (Table 2) showed significant increases in mean values of the SBP, HR and RPP during both treadmill and arm crank exercises in regarding baseline values p-value < 0.05, whereas the SBP, HR and RPP reduced significantly after both arm crank and treadmill exercises in regarding its values during exercise p-value < 0.05.

The repeated measure analysis (Table 3) showed significant differences between pre, during, and postconditions for pulse pressure, mean blood pressure, and heart rate recovery after one minute of the treadmill and arm crank exercises. Whereas an insignificant difference between pre, during, and post-test of mean blood pressure for treadmill exercis.

On comparison, there were significant differences in mean values of SBP between arm crank and treadmill both during exercise and after exercise (F-statistic = 88.543, 14.608, p-value<0.001) respectively. Also, there were significant differences in mean values of the HR both during and after both arm crank and treadmill exercises (F-statistic =42.510, 26.048, 8.822 and p-value<0.001, <0.001)

Table 1. The heart rate variability measures pre-and during treadmill and arm crank exercises.

Variables		Mean ± SD		95%CI	F-statistic	p-value
		Pre	During			
Treadmill	SDANN	62.07 ±13.15	41.61 ± 18.37	40.41-65.26	49.165	< 0.001
	SDNN	64.24 ±13.59	44.11 ±18.38	42.74-67.61	46.545	< 0.001
	RMSSD	46.86 ±16.96	26.69 ±13.43	23.46-50.08	52.181	< 0.001
Arm crank	SDANN	62.18 ±13.15	51.02 ±16.79	50.70-65.49	16.422	< 0.001
	SDNN	64,40 ±13.69	52.08 ±18.02	50.53-68.66	15.761	< 0.001
	RMSSD	46.94 ±17.00	32.94 ±14.04	30.36-49.02	24.167	< 0.001

SDANN: the standard deviation of the average normal-to-normal intervals. SDNN: the standard deviation of normal-to-normal intervals. RMSSD: the root means square of successive differences.

Table 2. Mean values of systolic blood pressure, heart rate, and rate pressure product pre, during, and post treadmill and arm crank exercises.

Variables		Mean ± SD	95% CI	F-value	p-value
1-Systolic blood pressure					
Treadmill	Pre	123.27±13.05	119.89-126.64	21.952	< 0.001
	During	132.17±2.83	131.44-132.89		
	Post	124.98± 1.95	124.43-125.54		
Arm crank	Pre	121.53±14.20	117.86-125.20	67.766	< 0.001
	During	139.70± 5.52	138.27-141.13		
	Post	126.35±1.65	125.89-126.81		
2-Heart rate					
Treadmill	Pre	78.57±5.41	77.17-79.96	1206.847	< 0.001
	During	125.17±2.37	124.55-125.78		
	Post	108.58±6.95	106.79-110.37		
Arm crank	Pre	77.68±6.71	75.95-79.42	1434.390	< 0.001
	During	130.15±5.43	128.75-131.55		
	Post	113.88±3.99	112.83-110.56		
3-Rate pressure product					
Treadmill	Pre	10.06±1.83	9.59-10.53	393.900	< 0.001
	During	16.66±0.88	16.43-16.88		
	Post	13.43±2.99	13.33-13.81		
Arm crank	Pre	9.91±1.95	9.41-10.42	542.349	< 0.001
	During	17.69±1.0	17.43-17.95		
	Post	14.38±0.55	14.52-14.50		

Table 3. Mean values of pulse pressure and mean arterial pressure at pre, during and post treadmill and arm crank exercises.

Variables		Mean± SD	95% CI	F-value	p-value
1-Pulse pressure					
Treadmill	Pre	41.08 ± 9.61	38.6-43.57	13.591	< 0.001
	During	49.85 ± 9.28	46.69-51.18		
	Post	41.75 ± 9.09	39.40-44.10		
Arm crank	Pre	40.6 ± 9.95	38.03-43.17	35.034	< 0.001
	During	56.13 ± 9.76	53.61-58.66		
	Post	44.92 ±11.66	41.90-47.93		
2-Mean blood pressure					
Treadmill	Pre	95.09 ± 8.86	92.80-97.38	5.912	0.003
	During	99.85 ± 6.13	97.96-101.13		
	Post	97.15 ± 5.91	95.62-98.68		
Arm crank	Pre	94.47 ± 9.17	92.90 - 96.84	16.136	< 0.001
	During	96.41 ± 9.97	94.34 - 98.46		
	Post	102.28 ±6.06	100.71 -103.84		
3-Heart rate recovery after one minute					
Treadmill		75.47± 9.91	73.94-76.99	15.433	< 0.001
Arm crank		80.93±9.01	78.60-83.26		

respectively. In addition, there were significant differences in mean values of the RPP & PP only during both arm crank and treadmill exercises (F-statistic=36.219,18.186, p-value=<0.001). There was a significant difference in the mean values of the heart rate recovery between arm crank and treadmill exercise table 3.

Discussion

Evaluation of cardiac autonomic function in response to exercise is a promising area in exercise physiology. This study was conducted to determine the differences between treadmill or arm crank exercise in response to autonomic cardiac functions. The findings showed significantly reduced HRV time domains during the treadmill and arm crank exercise. While comparing, the result showed that reduction of time domains was greater in favour of arm crank than treadmill exercise. The current result was supported with previous studies of Forjaz et al. [25], Segan et al. [26] and Ahmadian et al. [15]. Arm crank exercise is associated with a significant reduction of time domains in parallel with the significant increase in SBP, RPP, PP and HR [25, 26]. Ahmadian et al. [15] found a significant reduction in HRV measures during acute arm crank and leg cycle ergometer. They explained this reduction by increasing sympathetic modulation to accelerate heart rate and cardiac output to increase blood supply to active muscles [15]. Ahmadian et al. [15] also found that this significant reduction in HRV measures remains higher during arm crank than during leg cycle ergometer. This is parallel with existing findings, which show that the reduction in time domains is bigger during treadmill activity than with arm crank exercise. They referred to greater respiratory-induced sinus arrhythmia as changes in respiration, particularly the respiratory rate can modify HRV [18].

The current result contradicts the studies of Cottin et al. [27], Princi et al. [28], Weippert et al. [20] and Faria and Faria [29] found that time domains and frequency measures of HRV were greater during judo or sailing exercise than cycling exercise at a similar heart rate. They suggest a different sympathovagal modulation on cardiac function. Weippert et al. [20] found that dynamic isometric exercise accompanied a significant reduction in HRV time domains in parallel with a significant increase in SBP, HR, MABP and RPP. The current results also contradict the results of Faria and Faria [29], who found insignificant changes in cardiorespiratory response to either acute upper or lower body exercise. They compared arm rowing with leg extension exercise in which they used different modes of exercise than that used in the current study [29].

The current results proved significant increases in the HR, SBP and RPP during treadmill and arm crank exercise to provide adequate blood supply to active skeletal muscles. Myers supported these responses, who reported that the SBP increases progressively to achieve the highest value at maximal workload with a minor change in DBP [30]. Tulppo et al. found that arm crank is associated with higher HR than leg cycling exercise at equal maximal oxygen consumption (VO_2max). This may be due to rapid withdrawal vagal outflow during arm crank exercise [31].

The underlying physiological mechanisms may be due to increases in cardiovascular variables, sympathetic discharge, sympathovagal modulation of cardiac function [20,28], as well as an increase in sympathetic cardiac stimulation, adrenal glands and blood vessels [32]. The degree of vagal withdrawal and sympathetic stimulation depends mainly on applied exercise's mode and intensity [20, 28, 32]. Also, Di Blasio et al. found that movement of the upper body and breathing during arm crank exercise compete to recruit small muscle masses of the upper body and shoulder muscles [33]. The parasympathetic to sympathetic influence on the HR is 4:1 at rest, while during maximal intensity exercise, it reverses to approximately 1:4 [34]. The rate pressure product is the response of coronary circulation to myocardial metabolic demands, and it is the product of heart rate in systolic blood pressure. It is an easily measurable index that correlates with myocardial oxygen demand [35]. The presence of a statistically significant correlation between RPP, PP and spectral measures of short-term HRV supports a simplistic approach to autonomic assessment, in that easily measurable BP indices could be used as surrogates of HRV when it is not feasible to determine HRV indices directly [36].

The current result was expected during and after treadmill and arm crank exercise because participants had a well-functioning autonomic cardiac system. This result was supported with previous studies of De Almeida et al. [37], Robergs and Roberts [38], Ilias et al. [39], Forjaz et al. [25], Segan et al. [26], Toner et al. [40], Louhevaara et al. [41]. De Almeida et al. proved that arm and leg exercise is associated with significant increases in SBP, HR and RPP [37]. Robergs and Roberts proved that upper-limb exercise results in a greater cardiovascular strain, including greater HR and intra-arterial blood pressure for a given level of sub-maximal workload than lower-limb exercise [38]. Also, arm ergometers have been prone to subsequent cardiac events as arm exercise may not be sufficient to unmask a compromised cardiorespiratory system [39]. Toner et al. found that arm crank exercise significantly increases HR, SBP and RPP compared to lower limb exercises [40]. This elicits greater strain on the cardiovascular system during arm crank than during lower limb exercise. Thus, they suggested engagement of lower limb exercise to attenuate the strain placed on the cardiovascular system in cases

of the arm crank exercise [25, 26]. Toner et al. & Louhevaara et al. reported that as a result of reduced workload during arm-crank than during leg cycle ergometer exercise by 44% [40, 41], arm exercise makes more stress on the cardiorespiratory system than leg cycling exercise [42]. This may be explained by differences in physiological muscle mass and its properties. Lower and upper limb muscular mass represent 32% & 7.6% of total body muscle mass, respectively [43]. The absence of a muscular leg pump during arm crank exercise reduced venous return to the heart, leading to reduced ventricular filling and stroke volume. This will increase the production of catecholamine that accelerates both heart and respiratory rate in arm exercise compared with the combined arm and leg exercise [42]. The current results disagree with Coplan et al. study [21]. They found exercise at 85% of the predicted HR is associated with significant increases in the HR, SBP, VO_2max and RPP during treadmill than during arm-crank exercise. The current results also showed reductions in HR, SBP, RPP and MABP after stopping exercise. This may be due to the shift of autonomic control from sympathetic to parasympathetic control [44].

The current study's limitations include the lack of mixed gender, cohort, follow-up, intervention, and athletes or patients, all of which reduce the generalization of the study. In order to determine the comprehensive impact of treadmill and arm-crank exercise, future research should utilize intermittent follow-up, longitudinal effect, mix-gender, age categories, prospective effect, and athletes or patient-specific population.

Conclusions

Findings from the study suggest that treadmill exercise is more responsible for a greater significant reduction in mean values of HRV. This suggests that participants' parasympathetic withdrawal was less during treadmill exercises than arm crank exercises. The HR, SBP, PP, MABP and RPP significantly increased during arm crank than treadmill exercises. According to this study, there is higher sympathetic modulation during arm crank exercise than treadmill exercise. This study suggests that when recommending exercise to adult male individuals, the intensity and mode of exercise are crucial.

Conflicts of interest

The authors did not report any conflicts.

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