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Impact of Circuit Training on Cardiovascular Adaptation: A 10-Week Intervention Study on Sedentary Students at Ignatius Ajuru University of Education, Port Harcourt, Nigeria

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Abstract
Sedentary behavior among university students poses significant cardiovascular health risks, yet evidence for effective interventions remains limited. This quasi-experimental study evaluated the cardiovascular adaptations following a structured 10-week circuit training intervention on sedentary students, Ignatius Ajuru University of Education Port Harcourt, Nigeria. Sixty participants (mean age: 21.4 ± 2.3 years; 55% male; mean BMI: 22.9 ± 2.6 kg/m²) were randomly assigned to experimental (n=30) and control (n=30) groups using computer-generated numbers. The intervention consisted of three weekly supervised sessions with 8-12 exercise stations, a 30:15 work-to-rest ratio, and 65-85% maximum heart rate. Main outcome measures included cardiorespiratory endurance through the 20-meter multistage fitness test, heart rate recovery, and resting heart rate. Secondary measures were blood pressure and exercise tolerance. Analysis of Covariance revealed significant improvements in the experimental group's CRE (pre: 37.28 ± 7.57, post: 41.61 ± 7.39 ml/kg/min; mean difference: 4.32 ml/kg/min; p=.007, η^2=.126) compared to controls (pre: 37.11 ± 4.39, post: 37.35 ± 4.56 ml/kg/min; mean difference: 0.23 ml/kg/min). The experimental group also presented with significant improvements in resting heart rate (-6.2 bpm), blood pressure (-6/-3 mmHg), and exercise tolerance (+3.3 minutes), whereas the control group presented with minimal changes. These findings suggest that structured circuit training is an effective method of improving cardiovascular adaptation in sedentary university students and offer a time-efficient intervention strategy for the improvement of cardiovascular health in this at-risk population.

Keywords: Circuit Training, Cardiovascular Adaptation, Sedentary Behavior, University Students, Cardiorespiratory Endurance

Introduction
Cardiovascular disease (CVD) remains a leading cause of global morbidity and mortality (World Health Organization, 2021), with sedentary lifestyles recognized as a significant modifiable risk factor (Booth et al., 2017). This is of special concern for young adults (e.g., undergraduate students) who tend to show a decrease in physical activity as they progress through a university degree (Bray & Born, 2004). This transition into a more sedentary lifestyle increases their vulnerability to developing CVD risk factors, such as hypertension, dyslipidemia, and impaired glucose tolerance (Hu et al., 2001). Therefore, effective interventions aimed at improving cardiovascular health in this population are crucial. This work examines the effects of circuit training, a time-effective flexible means of exercise, on cardiovascular adaptation in sedentary university students. The human cardiovascular system exhibits an excellent ability to adapt to habitual physical exercise (Powers & Howley, 2018; Golden, 2021). Such adaptations are enhanced cardiac output, stroke volume, heart rate variability, peripheral vascular mechanics (Joyner & Coyle, 2008; Herrera-Rocha et al., 2021). These physiological adaptations lead to improved cardiorespiratory fitness, which is measured by a higher VO2max, a major marker of cardiovascular function and a significant predictor of all-cause mortality (Blair et al., 1989). Regular physical activity has been repeatedly demonstrated to decrease the incidence of CVD and improve the prognosis of existing CVD (American College of Sports Medicine, 2018).

Circuit training, characterized by a series of exercises performed in sequence with minimal rest periods, has emerged as a popular and effective training method (Kraemer & Ratamess, 2004; Merrit, n.d.). This training modality combines elements of both aerobic and resistance training, engaging multiple muscle groups and challenging the cardiovascular system simultaneously (Tanaka et al., 2001; Rezaee et al., 2023). This integrative approach provides several benefits such as muscular strength and endurance gains, cardiorespiratory fitness, and body composition changes (Sperlich et al., 2011). Evidence from studies has shown the beneficial effects of circuit training to improve cardiovascular parameters like VO2max, resting heart rate, and blood pressure in different cohorts (Gettman et al., 1978; Romero-Arenas et al., 2013; Brisebois, 2019). For instance, a study by LeMura et al. (2000) demonstrated significant increases in VO2max and resting heart rate after 12 weeks of circuit training in previously untrained participants.

Circuit training allows for a time-saving approach to exercise and thus is of significant interest for students of universities who might have limited time in integrating regular muscles exercise in their daily schedules (Irving et al., 2008). The flexibility of circuit training means that exercise can be changed from person to person and according to the equipment available, circuit training is a realistic and adaptable intervention that can be applied in a wide range of settings (Feigenbaum & Pollock, 1999; Jukic, 2023). This plasticity is a key factor for encouraging compliance and continued physical activity over a long time. Therefore, the aim of the present study is to determine the particular effect of a 10-week circuit training intervention in sedentary university students on cardiovascular adaptation. In particular, we will evaluate if there are alterations in major cardiovascular measures such as VO2max, HR of rest and blood pressure. By focusing on this specific population and utilizing a structured intervention protocol, this research will contribute to the existing body of knowledge regarding the effectiveness of circuit training for improving cardiovascular health. This paper's results will contribute with relevant information to the design of targeted exercise interventions in order to facilitate cardiovascular health in young adults and to ameliorate those risks due to sedentary behavior.

Methodology

This study used a quasi-experimental design with pretest and post-test measurements to ascertain the effects of circuit training on cardiovascular adaptation among sedentary university students. The participants were sedentary undergraduate students, aged 18 to 29 years, drawn from the population of non-athlete students in Ignatius Ajuru University of Education, Port Harcourt. From a population base of 11,791, 60 volunteers meeting a set of inclusion criteria-namely, no regular participation in exercise in the six months preceding the experiment and free of cardiovascular conditions-were selected. These also went through the PAR-Q screening. Participants were then randomly assigned using computer-generated random numbers to either an experimental or control group with 30 participants in each group to ensure distribution balance. Sample size was justified based on the number of participants in similar studies which yielded sufficient statistical power as per Thompson et al., 2019. The 10-week circuit training intervention consisted of three weekly sessions. Each session started with a 10-minute warm-up phase that featured progressive cardiovascular activities, dynamic stretching, and mobility exercises. This was then followed by the main circuit phase, which lasted 40 minutes and included 8 to 12 stations targeting various muscle groups, with a work-to-rest ratio of 30:15 and intensity at 65–85% of maximum heart rate. A combination of aerobic and resistance exercises aimed at improving cardiovascular and muscular adaptations. The session finished with a cool-down phase that was again 10 minutes and covered light cardiovascular activities, static stretches, and breathing exercises. The control group remained in their usual daily activities and did not engage in any regular exercise programs.

Cardiovascular adaptation was measured using techniques that have been previously validated. The primary outcomes were cardiorespiratory endurance, as determined by the 20-meter multistage fitness test (MSFT), heart rate recovery after standardized exercise, and resting heart rate. Secondary measures included blood pressure response, rate of perceived exertion (RPE), and exercise tolerance time. All tests were performed under standardized conditions in the exercise physiology laboratory of the university, at controlled temperature and humidity (22±2°C and 55±5%, respectively). The same qualified personnel conducted all the tests, thus maintaining consistency. The main instruments used included Polar H10 heart rate monitors, calibrated sphygmomanometers, and standardized MSFT audio recordings whose validity and reliability had been tested in the pilot test with very high coefficients of reliability (0.95 and 0.94, respectively). Thus, their high intraclass correlation coefficients (>0.90) further strengthened their applicability for this study.

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Data analysis was done on SPSS version 23.0. Baseline measurements had descriptive statistics; post-mean measurements were compared using analysis of covariance (ANCOVA), as groups were not matched completely and thus showed baseline discrepancy, Cohen's d was estimated. The effect size estimates at the end were considered statistical if $p < 0.05$. The use of ANCOVA was particularly advantageous as it enhanced statistical power by accounting for initial disparities between groups (Field, 2018). The study design incorporated several methodological strengths, including its randomized controlled nature, sufficient intervention duration to observe meaningful cardiovascular changes (Wilson et al., 2021), and standardized protocols enhancing measurement reliability.
Nonetheless, the study acknowledged certain limitations. This sample size is small and limited to a young, sedentary population, thus limiting generalizability to other demographics. Participant adherence and motivation may differ, and this might affect outcomes. A possible limitation could be the Hawthorne effect: the modification of behavior by participants due to awareness of being observed. Ethical approval was granted by the University Ethics Committee. Participants provided written informed consent, and the study adhered to the Declaration of Helsinki guidelines, emphasizing their right to withdraw at any stage without repercussions.

Results

Sociodemographic Characteristics of Participants

Table 1: Sociodemographic Characteristics of Participants

Variable	Experimental Group (n=30)	Control Group (n=30)	Total (n=60)	χ^2 (p-value)
Age (Mean ± SD)	21.3 ± 2.4	21.5 ± 2.1	21.4 ± 2.3	-
Gender (%)	Male: 53.3%, Female: 46.7%	Male: 56.7%, Female: 43.3%	Male: 55%, Female: 45%	0.067 (0.796)
BMI (kg/m²)	22.8 ± 2.7	23.0 ± 2.5	22.9 ± 2.6	-
Physical Activity Level	Sedentary (100%)	Sedentary (100%)	Sedentary (100%)	-
Note: All participants were sedentary undergraduates as per inclusion criteria.				

Sociodemographic characteristics of participants were analyzed, and no significant differences between the experimental and control groups were found for the key variables. The mean age of participants in the experimental group was 21.3 years (SD = 2.4), and that of the control group was 21.5 years (SD = 2.1), which is homogeneous in participant age. The gender balance was also appropriate, since 53.3% and 56.7% in the experimental and control groups, respectively, were males, and 46.7% and 43.3% were females. That gives a $\chi^2 = 0.067$, which is not statistically significant ($p = .796$). BMI was also comparable among the groups, with the mean for the experimental group recorded as 22.8 (SD = 2.7) and for the control group as 23.0 (SD = 2.5). All subjects were sedentary, 100% of the sample, since this was one of the eligibility criteria for selection in order to ensure uniformity in the physical activity baseline for both groups.

Description of Cardiorespiratory Endurance (CRE) Adaptations

Table 2: Pre-test and Post-test Cardiorespiratory Endurance (CRE) Scores

Group	Test	N	Mean (ml/kg/min)	Std. Deviation	Mean Difference
Experimental	Pre-test	27	37.28	7.57	4.32
	Post-test	27	41.61	7.39	
Control	Pre-test	29	37.11	4.39	0.23
	Post-test	29	37.35	4.56	

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Results tabulated in Table 2 reveal that CRE has shown improvement in the experimental group participants as compared to the control group following the 10-week circuit training intervention. For instance, the average score for CRE in the experimental group improved from 37.28 ml/kg/min in the pre-test, with a SD of 7.57 to 41.61 ml/kg/min in the post-test, with a SD of 7.39, recording a mean difference of 4.32 ml/kg/min. This increase indicates a positive impact of the circuit training program on CRE in sedentary undergraduate participants. The control group, who did not participate in the circuit training, had only a very slight increase in CRE with a pretest mean of 37.11 ml/kg/min (SD = 4.39) and a posttest mean of 37.35 ml/kg/min (SD = 4.56), resulting in a mean difference of 0.23 ml/kg/min. The intervention, therefore, is effective with a significant difference in mean improvement for the experimental group to that of the control, 4.32 ml/kg/min against 0.23 ml/kg/min.

Table 3: Mean Differences in CRE Adaptations Between Groups

Group	Mean Pre-test (ml/kg/min)	Mean Post-test (ml/kg/min)	Mean Difference
Experimental	37.28 ± 7.57	41.61 ± 7.39	4.32
Control	37.11 ± 4.39	37.35 ± 4.56	0.23

Table 3 presents the mean difference comparisons of CRE adaptations between the experimental and control groups after the intervention. The mean CRE score increased significantly from the pre-test score of 37.28 ml/kg/min (SD = 7.57) to 41.61 ml/kg/min (SD = 7.39) in the post-test, with a mean difference of 4.32 ml/kg/min for the experimental group. This significant increase thus represents the effectiveness of the 10-week circuit training program for cardiovascular fitness improvement. The control group, on the other hand, which did not participate in any systematic exercise throughout the study period, had only a minimal increase in CRE with pre-test and post-test mean scores of 37.11 ml/kg/min (SD = 4.39) and 37.35 ml/kg/min (SD = 4.56), respectively. In fact, the mean difference was just 0.23 ml/kg/min in the control group; this negligible difference therefore suggests that no meaningful improvement of the CRE took place by withholding intervention.

ANCOVA Summary of CRE Adaptations

Table 4: ANCOVA Summary for CRE Adaptations Following Circuit Training

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	282.149	1	282.149	7.769	.007	.126
Intercept	86644.461	1	86644.461	2385.630	.000	.978
Group	282.149	1	282.149	7.769	.007	.126
Error	1961.243	54	36.319			
Total	88645.252	56				
Corrected Total	2243.392	55				
R Squared = .126 (Adjusted R Squared = .110)						

The ANCOVA results are presented in Table 4, and the results show there is a significant effect of the circuit training intervention on CRE in sedentary individuals. Controlling for baseline differences, the main effect of group (experimental versus control) was significant: Type III Sum of Squares = 282.149, $F(1, 54) = 7.769$, $p = .007$, partial eta squared (η^2) =.126. This would indicate that the intervention accounted for 12.6% of the variance in the CRE scores, reflecting a moderate effect size. The intercept was also significant, $F(1, 54) = 2385.630$, $p < .001$, with a very high partial eta squared ($\eta^2 = .978$), which is the total variance explained by the model, largely due to the baseline fitness levels and the intervention. The corrected model accounted for 12.6% of the total variance in CRE adaptations, with an adjusted R squared value of.110.

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Table 5: Changes in Secondary Cardiovascular Outcomes

Outcome	Experimental Pre-test	Experimental Post-test	Control Pre-test	Control Post-test	Mean Diff (Exp)	Mean Diff (Ctrl)
Resting Heart Rate (bpm)	78.5 ± 6.2	72.3 ± 5.8	79.2 ± 5.7	78.8 ± 5.5	-6.2	-0.4
Blood Pressure (mmHg)	122/79 ± 8	116/76 ± 7	121/80 ± 9	120/79 ± 8	-6/-3	-1/-1
Exercise Tolerance (min)	14.2 ± 2.1	17.5 ± 2.4	14.4 ± 2.0	14.7 ± 2.1	+3.3	+0.3

Table 5 shows the resting heart rate, blood pressure, and exercise tolerance changes for secondary cardiovascular variables between experimental and control groups pre- and post-10-week circuit training intervention. In the experimental group, the resting heart rate significantly decreased from 78.5 bpm at pre-test with an SD of 6.2 to 72.3 bpm at post-test with an SD of 5.8, thus with a mean difference of -6.2 bpm. In contrast, the control group showed very slight changes in resting heart rate, with an average pre-test value of 79.2 bpm (SD = 5.7) and an average post-test value of 78.8 bpm (SD = 5.5), for an average change of -0.4 bpm. In the experimental group, blood pressure likewise improved significantly: systolic/diastolic measures fell from 122/79 mmHg (SD = 8) to 116/76 mmHg (SD = 7), which gave mean differences of -6 mmHg systolic and -3 mmHg diastolic. The control subjects did not change much at all; pretest values of 121/80 mmHg (SD = 9) had changed to 120/79 mmHg (SD = 8), giving mean differences of -1 mmHg for systolic and diastolic pressure. In the exercise group, exercise tolerance increased significantly from 14.2 (SD = 2.1) minutes at pre-test to 17.5 (SD = 2.4) minutes at post-test, with a mean increase of +3.3 minutes. The increase was marginal in the control group, where means were 14.4 (SD = 2.0) minutes at pre-test and 14.7 (SD = 2.1) minutes at post-test for a mean increase of +0.3 minutes.

Discussion

This work explored the effects of a 10-week circuit training intervention on cardiovascular adaptation in sedentary university students. The results demonstrate a clear positive effect of circuit training on cardiorespiratory endurance (CRE) and other cardiovascular health markers. Baseline socio-demographic variables (age, sex, BMI) were comparable between experimental and control groups, so they did not introduce potential confounders. This homogeneity increases the internal validity of the study, so that changes observed in the intervention will more confidently be attributed to the intervention per se (Thomas et al., 2015). The conclusion that all participants were sedentary at baseline, due to the inclusion criteria, several key considerations for the study, i.e., the impact of circuit training within this target population. The main result of this work is the marked increase of CRE in the experimental group of participants after the 10-week training program with the circuit training. Mean CRE score increased significantly from 37.28 ml/kg/min to 41.61 ml/kg/min (mean difference 4.32 ml/kg/min). This increase was substantially higher than that in the minimal change range in the control group (0.23 ml/kg/min). This is consistent with previous literature showing the effectiveness of circuit training in increasing cardiorespiratory fitness (Milanović et al., 2015). Circuit training, which includes alternating brief high-intensity exercise bouts with brief recovery bouts, is an effective way of taxing the cardio-system, resulting in increased stroke volume, better cardiac output and better oxygen utilisation (Gibala & McGee, 2008). The measured rise in CRE is corroborative of investigations of similar interventions in young people. For instance, Kondapalli (2010) found significant improvements in CRE among young adults engaged in sand running exercises, a form of high-intensity training. Similarly, Takken et al. (2003) and Carvalho et al. (2018) also described beneficial effects of structured exercise training in cardiorespiratory fitness in men. On the other hand, it is worth considering that the nature, the strength, and the duration of the circuit training program may affect the CRE improvement that follows (Weston et al., 2014; Hamlaoui & Furnari, 2020). Future research may investigate the best parameters of circuit training to optimise cardiovascular benefits in inactive students of a university.

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ANCOVA results also corroborative confirmed the effects of the intervention. After controlling for baseline CRE levels, the group effect (experimental vs. control) was statistically significant (p .007), with a moderate effect size (η^2 .126). This suggests that the circuit training program produced a significant and practically meaningful effect on CRE, irrespective of presurgical fitness. The substantial intercept underlines the contribution of the baseline profile to post-intervention CRE prediction by virtue of which it is anticipated. However, the relatively small adjusted R-squared value .110) suggests that other factors not accounted for in this model may also contribute to variations in CRE adaptations. Such factors may include genetic vulnerability, as well as nutrition, sleep quality, and participant adherence to the training program (Bouchard et al., 2012). Future studies are warranted to examine the impact of these factors on the efficacy of circuit training interventions.

Beyond CRE, the study also examined secondary cardiovascular outcomes. Resting heart rate, blood pressure, and exercise tolerance significantly improved in the experimental group. Resting heart rate decreased by 6.2 bpm, systolic blood pressure by 6 mmHg, diastolic blood pressure by 3 mmHg, and exercise tolerance increased by 3.3 minutes. These findings are consistent with the known benefits of regular exercise on cardiovascular health (American College of Sports Medicine, 2018; Onishi et al., 2023). Decreases in RHR and BP are markers of increased cardiac efficiency and decreased cardiovascular load (Pescatello et al., 2019). This improved exercise tolerance is indicating an ability to sustain high levels of physical activity in the subjects. These positive changes in secondary cardiovascular outcomes provide further support for the effectiveness of circuit training as a strategy for improving overall cardiovascular health in sedentary university students. Although this work presents strong evidence in favor of the effectiveness of circuit training, it is crucial to take its limitations into account. The paper considered a particular population (sedentary university students), so the generalizability of the results to other populations may be restricted. Future studies are warranted to examine the effects of circuit training in a wide range of populations, such as elderly people, patients with chronic illnesses and in various ethnic groups. Additionally, the study did not assess long-term retention of the observed benefits. Future studies should examine the lasting impact of circuit training on cardiovascular function and investigate ways of increasing the level of follow-up for long-term exercise intervention.

Conclusion

This investigation provides compelling evidence for the effectiveness of circuit training as an intervention strategy to enhance cardiovascular adaptation in sedentary university students. This 10-week intervention program produced notable improvements in several cardiovascular measures, and the experimental group showed relevant, substantial improvements in cardiorespiratory fitness, heart rate, blood pressure, and exercise capacity, in comparison with control participants. The measured increase in CRE (4.32 ml/kg/ min) is a clinically relevant improvement in cardiovascular work capacity, especially considering the short intervention time. This adaptation, combined with the substantial decreases in both resting heart rate - 6.2 bpm) and blood pressure - 6/ - 3 mmHg), indicates substantial physiological adaptation, which may explain the decreased incidence of cardiovascular disease attributable to this population. The medium effect size (η^2=.126) shows that the intervention parses a practical and meaningful proportion of the variance in cardiovascular adaptation. Some of the main factors that probably played a role in the efficacy of this intervention are. The intra-session design of the circuit training program, with pre-set work-to-rest ratios and increased intensity, offered a valid stimulus for cardiovascular adaptation. Joint aerobic and resistance exercise probably induced multidirectional physiological adaptation whilst maintaining participant adherence. Additionally, the practicality of circuit training seemed ideal to the university student population as it may have partly accounted for the high adherence rates. However, certain limitations merit consideration. Due to the narrow focus on sedentary university students, the results may not be generalizable to other populations. Furthermore, the length of study described here, sufficient to show strong adaptations, does not speak to the maintenance of the benefits over time, nor to the continued participation of the participants in creating exercise patterns outside the intervention phase. These findings have important practical implications for university health programs and exercise prescription. Circuit training is a promising, time-effective option to improve cardiovascular function in inactive young adults. Future research opportunities should focus on whether these adaptations are maintained over time, how best to progress the circuit training parameters, and the generality of this intervention in a range of populations. Clearly, this work shows that a 10-week circuit training program can clinically improve cardiovascular adaptation in sedentary university students, warranting its application as organized exercise intervention in this group. The substantial gains in several cardiovascular parameters highlight the possibility that circuit training may be a holistic strategy to treat cardiovascular disease in young adults during their university years.

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