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THE PHYSIOLOGICAL RESPONSE OF CARDIORESPIRATORY FITNESS PARAMETERS TO EXERCISE IN PREDIABETIC POPULATION: AN EXPERIMENTAL PRE- POST DESIGN

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ABSTRACT

Background: *The cardiorespiratory fitness in prediabetic population at pre- and post-interventional stage after 8 weeks of moderate intensity exercise was determined. This study is part of PhD project and carried out in Physiology department, Institute of Basic Medical Sciences, Khyber Medical University, Peshawar, Pakistan.* ***Methods:*** *It was an experimental study design. Adult prediabetics (n=50), 22 females and 28 males of 18 to 35y age group were included in the study. Diagnosis of prediabetes was made with HbA1c falling in the range of 5.7– 6.4%, and fasting blood glucose (100-125mg/dL). Cardiorespiratory fitness parameters (Ventilation, oxygen consumed during exercise VO2, carbon dioxide exhaled VCO2, metabolic equivalents (ME), heart rate (HR), heart rate reserve (HRR), rate of carbohydrate oxidation (RCHO), fat oxidation (RFO) and energy expenditure (EE)) were determined at pre- and post-exercise intervention using breath-by-breath analyzer. The participants performed moderate exercise protocol of 30 min with HRmax% of 70 ± 5% for 5 days a week for 8 weeks during their leisure time, monitored with pedometers.* ***Results:*** *The results showed a significant improvement in cardiorespiratory fitness parameters at post exercise analysis. Similar changes were observed for fasting blood glucose (P value < 0.001) and HbA1c (P value < 0.001).****Conclusion:*** *Moderate physical activity for 8 weeks showed significant Improvement in cardiorespiratory fitness parameters and glycemic status of patients with prediabetes.*

Key Words: Exercise, Prediabetes, glycemic status, cardiorespiratory fitness.

INTRODUCTION

Prediabetes is a preclinical stage with a higher risk of developing diabetes mellitus type 2 (T2DM) (Shimodaira et al., 2013). It has been reported by WHO (World Health Organization) that ‘’12.9 million people in Pakistan are diabetic with an estimated 38 million suffering from prediabetes (Wang et al., 2010). The second National Diabetes Survey of Pakistan conducted from

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February 2016 to August 2017, showed a prevalence of 26.3% for diabetes and 14.4% for prediabetes. The estimated count of prediabetics in the world is 314 million and is expected to rise by 2025 to 418 million (Akhtar et al., 2016).

The role of exercise as a treatment tool for DM and its complications is very well established (Powers et al., 2010) and as outlined by 'landmark Diabetes Prevention Program' that exercise is a standard therapeutic intervention for prevention of diabetes and prediabetes (Knowler et al., 2002). The assessment of functional capacity of the cardiorespiratory system is important in exercise physiology and sports medicine. The parameters used for cardiorespiratory fitness includes many parameters such as basal heart rate (BHR), heart rate reserve, oxygen uptake, carbon dioxide exhaled, VO_2/ VCO_2, VO_2/kg/min, Metabolic equivalents (METS) and energy expenditure (Akalan et al., 2008; Bruce et al., 1973). The prevalence of physical inactivity is on the rise and is being associated with modernization and use of gadgets. Approximately, 14% of adolescents and 30% of adults have been reported to be physically inactive (Hales et al., 2018). In addition, the prevalence of physical inactivity rises with age; 25% for young adults between 18–44 years, 33%, for 45–64 years age group, 36% for 65–74 years age group and 53% for elderly ≥ 75 years age (Kasiakogias & Sharma, 2020).

There are detrimental effects of inadequate physical activity on health. Increasing sitting time by one hour a day in type 2 diabetes mellitus increases the mortality risk by 13%. Furthermore, inactive lifestyle can lead to poor circulation, arthritis, osteoporosis, less social interactions, and overall poor quality of life (Liu et al., 2018; Mondal & Mishra, 2017). Regular exercise ensures good health; however, intense, irregular, or unplanned physical activity can have detrimental effects on health (Yavari et al., 2015).

Sub-maximal exercise testing has become very popular, because it reduces the risk of adverse events and is safer than maximal exercise testing. There is no structured protocol till date in literature that can guide exercise physiologists, medical personnel, sport scientists towards an appropriate 'sub-maximal protocol selection' (Akalan et al., 2008). The modalities mostly used are stepping, walking, cycling, and running.

Treadmill exercise is ideal for gym and clinical testing because the speed is well defined and can be monitored. Walk, run, or step count can be used as a modality for exercise but step count is ideal in different settings and can be given to a wider population, monitored with pedometers (Gibbons et al., 2001). In addition, little is known about the effect of planned exercise activity for prolonged duration on the cardiorespiratory fitness in prediabetics population. Due to non-availability of any pharmaceutical management for prediabetes, regular physical activity can be considered as one of the best alternatives. As it is evident from the literature that development of diabetes is a multi-factorial complex process and can lead to deranged cardiorespiratory fitness parameters. The current study is therefore designed to find out the effect of regular exercise of moderate intensity for 8 weeks on the cardiorespiratory fitness of prediabetics.

METHODS

Experimental design

It was an experimental study design with convenience sampling. All experimental work was carried out from February 2019 – January 2020 in the Physiology Department, Institute of Basic Medical Sciences (IBMS) Khyber Medical University (KMU) Peshawar, Pakistan. Ethical approval for the study was granted by Ethical review board of Khyber Medical University under letter No: DIR/KMU-EB/BP/000580 dated 09/04/2019 and all the procedures were carried in accordance with declaration of Helsinki 1964. The Prediabetic volunteers 18 to 35y, n=50; with sedentary lifestyle were included in the study with no history of chronic or active health problem. The inclusion criteria for prediabetes were fasting blood glucose (FBG) level 100 -125 mg/dL and HbA1c between 5.7 - 6.4% according to American Diabetes Association, 2014 (Herman, 2017). After explaining the procedure to each participant, consent (informed) was taken. Those with diabetes mellitus, hypertension, renal disease, or any other chronic or active disease were excluded from the study. The International Physical Activity Questionnaire (IPAQ) short form was filled (Cerqueira et al., 2020). Dietary history was taken through 24-hour dietary recall questionnaire (Uhm et al., 2017).

Exercise Test

The exercise tests were done in skill lab of IBMS, KMU. The volunteers were made to walk on motorized treadmill (Revo RT, Taiwan) for 45min (including 5 minutes warm up and 10 minutes cool down) at 70 ± 5 % of maximal heart rate (Thirupathi & Pinho, 2018) and step counts during this activity were counted with pedometers (Mi band 2, China). The step counts were standardized for each participant, and they completed the study by performing the same protocol for 5 days a week for 8 weeks monitoring the step count with the provided pedometers. Cardiorespiratory fitness parameters including basal heart rate (BHR), heart rate reserve, oxygen uptake, carbon dioxide exhaled, VO_2/ VCO_2, VO_2/kg/min, Metabolic equivalents (METS) and energy expenditure (EE) of the participants were determined through breath-by-breath analyzer (Cosmed, Italy).

Statistical Analysis

SPSS version 20 was used for analysis. Normality was checked for all variables by Kolmogorov Smirnov and Shapiro Wilk normality tests and histograms. The glycemic status and cardiorespiratory fitness parameters were expressed as mean ± Standard deviation. Pre and post intervention values of study variables were compared by paired sample t test. $P \leq 0.05$ was considered statistically significant.

RESULTS

Of the 50 participants, females were 22 (44%) with mean age 27.64 ± 6.1 years and males were 28 (56%) with mean age 30.18 ± 3.86 years. A significant improvement in cardiorespiratory fitness parameters was observed at post-intervention analysis. In addition, statistically significant decrease was observed at post-intervention for FBG from 110 ± 7 mg/dl to 93.24 ± 10 mg/dl ($P < 0.001$) and HbA1c from 6.02 ± 0.24 % to 5.66 ± 0.29 % ($P < 0.001$).

The mean values of breath-by-breath analysis data are shown in table 1. The statistically significant results are highlighted. Ventilation (VE), oxygen consumed (VO_2), carbon dioxide exhaled (VCO_2), VO_2/kg, metabolic equivalents (METS), heart rate (HR), rate of carbohydrate oxidation (RCHO) and energy expenditure (EE) values were higher at pre- intervention while heart rate reserve (HRR) and rate of fat oxidation (RFO) were lower at pre- intervention. However, after 8 weeks of exercise intervention, they showed improved cardiorespiratory fitness and were able to do the same physical activity at lower VO_2, VCO_2, VO_2/kg, METS, and EE while fat oxidation and heart rate improved also reflect improved fitness as shown in table 1.

Table 1: ***Comparison of Mean Values of Cardiorespiratory Fitness***

#	Cardiorespiratory Fitness	Mean ± SD n = 50		P value
		Pre-Intervention	**Post-Intervention**	
1	VE (L/min)	35.3 ± 9.16	32.17 ± 6.4	**0.012**
2	VO_2 (ml/min)	1091 ± 287	1023 ± 210	0.113
3	VCO_2 (ml/min)	979 ± 283	874 ± 186	**0.014**
4	RQ	0.89 ± 0.05	0.86 ± 0.03	**< 0.001**
5	VO_2/Kg (ml/min/kg)	14.96 ± 2.64	13.91 ± 1.53	**0.003**

6	METS	4.27 ± 0.75	3.98 ± 0.44	**0.003**
7	HR (bpm)	123.08 ± 7.71	118.12 ± 8.56	**0.001**
8	HRR (bpm)	67.37 ± 8.33	72.97 ± 10.18	< **0.001**
9	RFAT (kcal/30min)	56.65 ± 25	72.35 ± 20.42	< **0.001**
10	RCHO (kcal/30min)	103.73 ± 46.3	76.3 ± 24.7	< **0.001**
11	EE (kcal/30min)	167 ± 39.67	140 ± 29.5	< **0.001**

VE = ventilation, VO2 = oxygen consumed, VCO2 = carbon dioxide exhaled, RQ = Respiratory Quotient, METS = metabolic equivalents, HR = heart rate, HRR = heart rate reserve, RFO = fat oxidation, RCHO = carbohydrates oxidation, EE = energy expenditure. $P \leq 0.05$ is considered statistically significant.

DISCUSSION

The prime objective of the study was to determine the cardiorespiratory fitness of all the participants at pre-and post- interventional stage through breath-by-breath analyzer. The different parameters including respiratory quotient (RQ), oxygen consumed (VO_2), carbon dioxide exhaled (VCO_2), oxygen consumed per kg (VO_2/kg), metabolic equivalents (METS), energy expenditure (EE), heart rate (HR), heart rate reserve (HRR), carbohydrate and fat oxidation were taken into consideration. The cardiorespiratory fitness of the participants improved significantly as determined by decrease in RQ ($P < 0.001$), VO_2 ($P = 0.113$), EE ($P < 0.001$), METS ($P = 0.003$), carbohydrate oxidation ($P < 0.001$). and HR ($P = 0.001$) at post- intervention, while heart rate reserve ($P < 0.001$) and fat oxidation ($P < 0.001$) increased at post- intervention. Our results are supported by Gaitán *et al.*, 2019 who reported an increase in fat oxidation ($P < 0.001$) whereas CHO oxidation declined at post- interventional stage (Naves et al., 2018). Similarly, the decrease in heart rate and improved heart rate reserve is consistent with the findings of Plaza *et al.*, 2019 (Plaza-Florido et al., 2019). The most likely mechanism involved in improving cardiorespiratory fitness is enhanced activity of lipoprotein lipase in skeletal muscle that can lead to greater clearance rate of TGs, transport of lipids to the liver and improved HDL level (Goodrich et al., 2012).

Current research literature supports the fact that enhanced physical activity leads to optimal function of the physiological systems of the human body. It can improve myocardial function, by lowering oxygen demand and increasing myocardial strength consistent with our findings. In addition, decreasing blood pressure and energy expenditure are signs of improved cardiorespiratory fitness. All these adaptations result in improved overall health without the side effects of medicines. Therefore, the intervention adopted in this study can be used as a tool in prevention and treatment of prediabetes, diabetes, and other chronic diseases (Anderson & Durstine, 2019; Lavie et al., 2015).

CONCLUSIONS

Enhanced physical activity had a significant effect on improving the glycaemic status and cardiorespiratory fitness at post intervention. Future studies must focus on the best preventive methodologies, incorporating physical fitness programs for prediabetes and diabetes prevention and management with limited financial resources especially in developing countries like Pakistan and in other diverse settings.

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REFERENCES

Akalan, C., Robergs, R., & Kravitz, L. (2008). Prediction of VO2max from an individualized submaximal cycle ergometer protocol. *Journal of Exercise Physiology Online*, *11*(2), 1–17.

Akhtar, S., Khan, Z., Rafiq, M., & Khan, A. (2016). Prevalence of type II diabetes in district Dir Lower in Pakistan. *Pakistan Journal of Medical Sciences*, *32*(3), 622–625. https://doi.org/10.12669/pjms.323.9795

Anderson, E., & Durstine, J. L. (2019). Physical activity, exercise, and chronic diseases: A brief review. *Sports Medicine and Health Science*, *1*(1), 3–10.

Bruce, R., Kusumi, F., & Hosmer, D. (1973). Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. *American Heart Journal*, *85*(4), 546–562.

Cerqueira, É., Marinho, D. A., Neiva, H. P., & Lourenço, O. (2020). Inflammatory effects of high and moderate intensity exercise—A systematic review. *Frontiers in Physiology*, *10*, 1550.

Gibbons, W. J., Fruchter, N., Sloan, S., & Levy, R. D. (2001). Reference values for a multiple repetition 6-minute walk test in healthy adults older than 20 years. *Journal of Cardiopulmonary Rehabilitation and Prevention*, *21*(2), 87–93.

Goodrich, K. M., Crowley, S. K., Lee, D., Sui, X. S., Hooker, S. P., & Blair, S. N. (2012). Associations of cardiorespiratory fitness and parental history of diabetes with risk of type 2 diabetes. *Diabetes Research and Clinical Practice, 95*(3), 425–431.

Hales, C. M., Fryar, C. D., Carroll, M. D., Freedman, D. S., & Ogden, C. L. (2018). Trends in obesity and severe obesity prevalence in US youth and adults by sex and age, 2007-2008 to 2015-2016. *Jama*, *319*(16), 1723–1725.

Herman, W. H. (2017). The global burden of diabetes: an overview. *Diabetes Mellitus in Developing Countries and Underserved Communities*, 1–5.

Kasiakogias, A., & Sharma, S. (2020). Exercise: The ultimate treatment to all ailments? *Clinical Cardiology*, *43*(8), 817–826.

Knowler, W. C., Barrett-Connor, E., Fowler, S. E., Hamman, R. F., Lachin, J. M., Walker, E. A., & Nathan, D. M. (2002). Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *The New England Journal of Medicine*, *346*(6), 393–403.

Lavie, C. J., Arena, R., Swift, D. L., Johannsen, N. M., Sui, X., Lee, D., Earnest, C. P., Church, T. S., O'Keefe, J. H., & Milani, R. V. (2015). Exercise and the cardiovascular system: clinical science and cardiovascular outcomes. *Circulation Research*, *117*(2), 207–219.

Liu, Y., Shu, X.-O., Wen, W., Saito, E., Rahman, M. S., Tsugane, S., Tamakoshi, A., Xiang, Y.-B., Yuan, J.-M., & Gao, Y.-T. (2018). Association of leisure-time physical activity with total and cause-specific mortality: a pooled analysis of nearly a half million adults in the Asia Cohort Consortium. *International Journal of Epidemiology*, *47*(3), 771–779.

Mondal, H., & Mishra, S. P. (2017). Effect of BMI, body fat percentage and fat free mass on maximal oxygen consumption in healthy young adults. *Journal of Clinical and Diagnostic Research: JCDR*, *11*(6), CC17.

Naves, J. P. A., Viana, R. B., Rebelo, A. C. S., de Lira, C. A. B., Pimentel, G. D., Lobo, P. C. B., de Oliveira, J. C., Ramirez-Campillo, R., & Gentil, P. (2018). Effects of high-intensity interval training vs. sprint interval training on anthropometric measures and cardiorespiratory fitness in healthy young women. *Frontiers in Physiology*, *9*, 1738.

Plaza-Florido, A., Migueles, J. H., Mora-Gonzalez, J., Molina-Garcia, P., Rodriguez-Ayllon, M., Cadenas-Sanchez, C., Esteban-Cornejo, I., Solis-Urra, P., De Teresa, C., & Gutiérrez, Á. (2019). Heart rate is a better predictor of cardiorespiratory fitness than heart rate variability in overweight/obese children: The ActiveBrains project. *Frontiers in Physiology*, *10*, 510.

Powers, S. K., Duarte, J., Kavazis, A. N., & Talbert, E. E. (2010). Reactive oxygen species are signalling molecules for skeletal muscle adaptation. *Experimental Physiology*, *95*(1), 1–9.

Shimodaira, M., Niwa, T., Nakajima, K., Kobayashi, M., Hanyu, N., &

Nakayama, T. (2013). Correlation between mean platelet volume and fasting plasma glucose levels in prediabetic and normoglycemic individuals. *Cardiovascular Diabetology*, *12*(1), 1–7. https://doi.org/10.1186/1475-2840-12-14

Thirupathi, A., & Pinho, R. A. (2018). Effects of reactive oxygen species and interplay of antioxidants during physical exercise in skeletal muscles. *Journal of Physiology and Biochemistry*, *74*(3), 359–367.

Uhm, K. E., Yoo, J. S., Chung, S. H., Lee, J. D., Lee, I., Kim, J. Il, Lee, S. K., Nam, S. J., Park, Y. H., & Lee, J. Y. (2017). Effects of exercise intervention in breast cancer patients: is mobile health (mHealth) with pedometer more effective than conventional program using brochure? *Breast Cancer Research and Treatment*, *161*(3), 443–452.

Wang, H., Shara, N. M., Calhoun, D., Umans, J. G., Lee, E. T., & Howard, B. V. (2010). Incidence rates and predictors of diabetes in those with prediabetes: The Strong Heart Study. *Diabetes/Metabolism Research and Reviews*, *26*(5), 378–385. https://doi.org/10.1002/dmrr.1089

Yavari, A., Javadi, M., Mirmiran, P., & Bahadoran, Z. (2015). Exercise- induced oxidative stress and dietary antioxidants. *Asian Journal of Sports Medicine*, *6*(1).