MPRA

Long-Term Regular Exercise Increases VO2max for Cardiorespiratory Fitness

Mohajan, Devajit and Mohajan, Haradhan

Department of Civil Engineering, Chittagong University of Engineering Technology, Chittagong, Bangladesh, Department of Mathematics, Premier University, Chittagong, Bangladesh

3 February 2023

Long-Term Regular Exercise Increases $\dot{V}O_2$max for Cardiorespiratory Fitness

Devajit Mohajan

Department of Civil Engineering, Chittagong University of Engineering & Technology, Chittagong, Bangladesh

Email: devajit1402@gmail.com

Mobile: +8801866207021

Haradhan Kumar Mohajan

Department of Mathematics, Premier University, Chittagong, Bangladesh

Email: haradhan1971@gmail.com

Mobile: +8801716397232

Abstract

This study tries to discuss maximum oxygen consumption ($\dot{V}O_2$max) strategy and its importance to build up a healthy society worldwide. $\dot{V}O_2$max is an important predictive factor of cardiovascular health, morbidity, and all-cause mortality; and consider it as the gold standard measure of cardiorespiratory fitness. Regular and long-time physical exercise, and exercise training are effective means of increasing $\dot{V}O_2$max. This research aims to increase $\dot{V}O_2$max and endurance capacity through the prolonged strenuous exercise, hardworking, and exercise training.

Keywords: $\dot{V}O_2$max, exercise, cardiorespiratory fitness

1. Introduction

$\dot{V}O_2$max is the maximum rate of oxygen consumption capacity during an intense physical effort, which is an indicator of the basic concepts of physical fitness. Here "V" is for volume, "O_2" for oxygen, "max" for maximum, and the dot over V means per unit of time (Smirmaul et al., 2013). When a gymnast increases exercise intensively, oxygen consumption will eventually be either plateau or decrease slightly, even with further increase in intensity of exercise; then s/he will confirm that s/he has reached in the $\dot{V}O_2$max (McArdle et al., 2010). The concept of maximal oxygen uptake ($\dot{V}O_2$max) and oxygen (O_2) debt is developed in 1922 by the British physiologist Archibald Vivian Hill (1886-1977) (Hill, 1926; Hale, 2008).

$\dot{V}O_2$max is an indication of cardiorespiratory fitness (CRF). It incorporates multiple organ systems that are influenced by a number of factors, from respiration to end-organ oxygen consumption; and later consume through the cellular metabolism (Stringer, 2010). Factors that determine $\dot{V}O_2$max are heart-lung function, age, aerobic muscle metabolism, body fatness, state of exercise, genetics, gender, and multivitamin (Huldani et al., 2020; Mohajan & Mohajan, 2023c,d). When an individual organize exercise, the increase in metabolism is expressed as the whole-body oxygen uptake that increases with exercise intensity to reach at $\dot{V}O_2$max (Moxnes & Hausken, 2012).

$\dot{V}O_2$max is also called cardiopulmonary exercise testing (CPET) and it is considered as an exercise stress test. It reflects cardiorespiratory fitness and endurance capacity for a heavy exercise or any laborious work. The results during exercise show the fitness level and aerobic endurance of a gymnast (Dlugosz et al.,

2013). $\dot{V}O_2$max can be expressed in two ways as; i) absolute, where unit of $\dot{V}O_2$max is liters of oxygen per minute (L/min), and ii) normalized, milliliters of oxygen per kilogram of subject bodyweight per minute (mL/kg/min). The latter is used to compare the performance of endurance sports athletes (Scribbans, 2016).

The velocity that is reached at $\dot{V}O_2$max is called $v\dot{V}O_2$max, and the time that $v\dot{V}O_2$max can be sustained for is called T_{max}. When a person start physical exercises, increase in plasma volume that results in increased venous return. Consequently, increased end-diastolic volume, there is decreased cardiac afterload. Consequently, stroke volume of the person increases (Maughan & Leiper, 1983; Little et al., 2010).

2. Literature Review

To be familiar with the research field, literature review is an important item for a researcher. In any research, it is a starting section, where works of previous researchers are emphasized (Polit & Hungler, 2013). It helps the new researchers to understand the subject area for performing their research efficiently (Creswell, 2007). Shahinaj Dcosta and her coauthors have wanted to assess the cardiorespiratory fitness using $\dot{V}O_2$max and endurance among healthy males who are involved in regular exercise in gymnasium. They have found that there is statistically significant improvement in $\dot{V}O_2$max and endurance with duration of exercise, i.e., regular exercise improves the $\dot{V}O_2$max and endurance (Dcosta et al., 2022). Steven A. Hawkins and Robert A. Wiswell have shown that cardiorespiratory fitness on quality of life, cardiovascular disease and all-cause mortality are age-related, and with advancing age $\dot{V}O_2$max decreases. Over the age of 70 years, the decline in $\dot{V}O_2$max seems to be reduced both in maximal heart rate

(HRmax) and lean body mass (LBM). Exercise training does not influence declines in HRmax, but LBM can be maintained to some degree by physical exercise (Hawkins & Wiswell, 2003).

Andrzej Klusiewicz and his coauthors have explained the usefulness of indirect methods of assessment of $\dot{V}O_2$max to estimate physical capacity of trained male and female rowers during a training cycle. In their study they have observed that two elaborated methods of estimation of maximal oxygen uptake yield more accurate results in male compared to female rowers (Klusiewicz et al., 2016). Anabel N. Rodrigues and her coworkers have noticed that inactivity is a growing problem that affects an ever growing number of children and adolescents. The identification of population levels of $\dot{V}O_2$max is an aid to studies that propose to relate physical fitness to cardiovascular risk for prescribing exercise and analyzing the effects of training (Rodrigues et al., 2006). Devajit Mohajan and Haradhan Kumar Mohajan have tried to discuss obesity and overweight with their physical effects (Mohajan & Mohajan, 2023a-q). They have also stressed on various indices, such as Body Mass Index (BMI), Ponderal Index, and Broca Index with their importance in health sciences (Mohajan & Mohajan, 2022a-j).

Stephen Seiler has informed that hundreds of laboratories are doing physiological tests on endurance athletes. In these labs three core variables are routinely measured, such as the maximal oxygen consumption, the lactate threshold, and work economy or efficiency (Seiler, 2011). Süleyman Gönülateş wants to determine whether there is a difference between the $\dot{V}O_2$max values in the field and laboratory test. He has obtained that the $\dot{V}O_2$max value in the applications of the laboratory environment is higher than the $\dot{V}O_2$max value in the applications of the field test (Gönülateş, 2018).

John F. Moxnes and Kjell Hausken present a theoretical study comparing the improvement of the whole body $\dot{V}O_2max$ when training is performed at different intensities. They compare $\dot{V}O_2max$ improvement in five training methods. Later, they have established a weight function that is important for aerobic utilization and stroke volume utilization (Moxnes & Hausken, 2012). Daizong Wen and his coauthors have examined the effects of different protocols of high-intensity interval training (HIIT) on $\dot{V}O_2max$ improvements in healthy, overweight/obese and athletic adults, based on the classifications of work intervals, session volumes and training periods (Wen et al., 2019). J. Susie Woo and her coauthors want to determine whether changes in oxygen efficiency occur with aging or exercise training in healthy young and older subjects. Exercise capacity declines with age and also improves with exercise training (Woo et al., 2006).

3. Research Methodology of the Study

There is no alternative but research to an academician and it is considered as an essential and influential work for his/her carrier development (Pandey & Pandey, 2015). Methodology is a clear guideline to do a good research that follows scientific methods properly (Kothari, 2008). It tries to describe the types of research and the types of data (Somekh & Lewin, 2005). Therefore, research methodology is a working procedure for planning, arranging, designing, and conducting a meaningful and valuable research (Remenyi et al., 1998; Legesse, 2014). In this mini review we have started main body of research with a discussion on aerobic and anaerobic fitness capacity and boundary level of $\dot{V}O_2max$. Then we have stressed on $\dot{V}O_2max$ measurements methods. Also we have observed and worked on $\dot{V}O_2max$ variations due to age, sex and hemoglobin level. Finally, we

have briefly highlighted the benefits of $\dot{V}O_2max$ (Mohajan et al., 2012, 2013). To prepare this paper we have consulted books of famous authors, national and international journals, handbooks, theses, etc. (Islam et al., 2009a,b, 2010, 2011, 2012a,b,c, Mohajan, 2011a,b, 2012a-f, 2013a-g, 2014a-g, 2015a-e, 2016a,b, 2017a-e, 2018a-e,2020a-e, 2021a-d, 2022a-d, Rahman & Mohajan, 2019, Roy et al., 2009).

4. Objective of the Study

The key objective of this study is to discuss $\dot{V}O_2max$ in some details. Other minor related objectives of the study are as follows:

- to highlight on benefit of $\dot{V}O_2max$
- to show variation of $\dot{V}O_2max$ due to age and sex level, and
- to indicate boundary of $\dot{V}O_2$ max.

5. Aerobic and Anaerobic Fitness Development

Aerobic fitness depends on cardiovascular, respiratory, and hematological components that are determined by means of the cardiopulmonary exercise testing. Regular long-term exercise increases $\dot{V}O_2max$ by increasing stroke volume and arteriovenous oxygen difference. Physical exercise increases quantity and activity of key enzymes of glycolysis to develop endurance of a person (Dcosta et al., 2022). Aerobic fitness is typically measured as $\dot{V}O_2max$ and is used frequently as an indicator of cardiorespiratory fitness (Wen et al., 2019). Higher relative aerobic capacity represents better physical performance and lower risk of cardiovascular/coronary heart diseases and all-cause mortality (Kodama et al., 2009).

High-intensity interval training (HIIT) is an effective alternative approach for improving $\dot{V}O_2max$ in healthy, overweight/obese, and athletic adults. It improves both aerobic and anaerobic fitness, and also improves endurance performance (Wen et al., 2019). When high-intensity exercise is done by a gymnast or an athlete for a few seconds, adenosine triphosphate (ATP) is resynthesized by both aerobic and anaerobic processes, which are conventionally evaluated by $\dot{V}O_2max$. Due to high-intensity exercise an athlete's ability is grown up to release energy both aerobically and anaerobically (Taylor et al., 1955).

6. Boundary Level of $\dot{V}O_2max$

The untrained healthy males and females can achieve a $\dot{V}O_2max$ about 35-40 and 27-31 mL/(kg.min) respectively (Heyward, 2010). The $\dot{V}O_2max$ values for elite athletes can be achieved above 90 mL/(kg.min), mice have about 140 mL/(kg.min), running horses have about 193 mL/(kg.min). Some strength animals, such as Alaskan huskies can be achieved $\dot{V}O_2max$ values as high as 240 mL/(kg.min), and pronghorn antelopes have as high as 300 mL/(kg.min) (Lindstedt et al., 1991; Dlugosz et al., 2013; Smirmaul et al., 2013).

7. Measurement of $\dot{V}O_2max$

$\dot{V}O_2max$ measurements are used for prescribing exercise and analyzing the effects of training programs, and to relate physical fitness against cardiovascular risks (Rodrigues et al., 2006). $\dot{V}O_2max$ is the golden standard measure for the individual's aerobic fitness level. A commonly used value for O_2 consumption at rest is 125 mL O_2 per minute per square meter of body surface area during an

intense, maximal effort. $\dot{V}O_2$max can be estimated from a race performance through many tests, such as the Cooper test, Rockport method, Bruce Treadmill Test, Harvard step test, etc. (Cooper, 1968; Dcosta et al., 2022). The measurement of cardiac output can be performed using Fick equation, which is developed in 1870 by German born physician and physiologist Adolf Eugen Fick (1829-1901), and can be written as (Fick, 1870),

$$VO_2 = CO \times \left(C_a O_2 - C_v O_2 \right) \qquad (1)$$

where CO is cardiac output, VO_2 is oxygen consumption (mL/min), $C_a O_2$ is arterial oxygen consumption, and $C_v O_2$ is venous oxygen consumption (Gazibarich et al., 2019). Equation (1) provides us the information that the rate of oxygen uptake from alveolar gas. The term $\left(C_a O_2 - C_v O_2 \right)$ is also known as the arteriovenous oxygen difference (Ross et al., 2016). The concept of accumulated oxygen deficit is first introduced by Danish Professor August Krogh (1874-1949) and a Danish physiologist and gymnastic writer Johannes Lindhard (1870-1947) in 1920 (Krogh & Lindhard, 1920).

8. $\dot{V}O_2$max Due to Age, Sex, and Hemoglobin Level

$\dot{V}O_2$max has a strong relationship with age. The functions of heart and lungs are different between young and elderly people. The $\dot{V}O_2$max of elderly people decreased due to decline function of the lungs, heart, and blood vessels. The age level of 20-30 years is the peak age of the endurance of the heart and lungs of human body, and then $\dot{V}O_2$max will decrease with age (Woo et al., 2006). Age-related loss of $\dot{V}O_2$max seems to occur in a non-linear manner in association with declines in physical activity (Pugh & Wei, 2001). Older age, female, and the untrained state are related to decrease in exercise capacity and also decrease

$\dot{V}O_2$max. Maximum heart rate is decreased with aging and stroke volume is reduced in females and the untrained persons (Woo et al., 2006).

$\dot{V}O_2$max are different for male and female due to differences in composition and body size, and also a male has more hemoglobin concentrations than a female, which binds more oxygen to produce energy. A woman's body carries more fat than men which causes women to have a smaller $\dot{V}O_2$max (McArdle et al., 2006). It is evidence that the $\dot{V}O_2$max a 10% decline per decade in men and women regardless of activity level from age 20 to 60 years (Robinson, 1938; Rogers et al., 1990) and a 22% decline per decade in athletes over the age of 70 years (Pollock et al., 1974). Also high intensity exercise is maintained for a long-term, may reduce this loss up to 50% in young and middle-aged men, but not in older men (Meredith et al., 1987). On the other hand, middle-aged and older women do not appear to be able to reduce this loss less than 10% per decade (Hawkins & Wiswell, 2003).

9. Benefit of $\dot{V}O_2$max

A gymnast can know the maximum heart beats per minute at the maximum working situation. S/he can realize the starting time of lactic acid gathering starts in the muscles during anaerobic threshold (Buttar et al., 2019). Also s/he can determine the level of efforts of aerobic threshold before anaerobic threshold. After few weeks of exercise, there is increased red blood cell volume; increased vascular function, increased capillary density, and increased mitochondrial volume density thus increase oxidative capacity (Ross et al., 2016; Dcosta et al., 2022).

Prolonged and rhythmic regular exercise increases cardiorespiratory endurance. If an individual is not accompanied by regular exercise, cardiorespiratory fitness

must decline (Fleg et al., 2005). Well-established risk factors, such as hypertension, diabetes, smoking and obesity, hypercholesterolemia, and cardiovascular fitness are more powerful predictors of mortality, and $\dot{V}O_2$max practice can reduce these to lead a healthy life (Myers et al., 2002; Mohajan & Mohajan, 2023a,b).

10. Conclusions

In this study we have observed that $\dot{V}O_2$max is one of the most fundamental measures of human physiology. Regular and long-term routinely exercises can present human beings a healthy and quality life. We have realized that exercise efficiency and exercise capacity are decreased in older age. Also $\dot{V}O_2$max varies on gender, and women have lower $\dot{V}O_2$max than men. We have also understood that maintaining cardiovascular fitness we can reduce the risk of all-cause morbidity, mortality, and cardiovascular diseases. Insufficient physical activity results overweight and obesity that are the risk factors of various non-communicable diseases (NCDs), such as cardiovascular disease, stroke, diabetes, cancers, etc. Physical activity and life style modification irrespective of age are the key factors for primary prevention of cardiovascular, metabolic, and mental disorders.

References

Buttar, K. K. et al. (2019). A Review: Maximal Oxygen Uptake (VO_2max) and Its Estimation Methods. *International Journal of Physical Education, Sports and Health*, 6(6), 24-32.

Cooper, K. H. (1968). A Means of Assessing Maximal Oxygen Intake. Correlation between Field and Treadmill Testing. *The Journal of the American Medical Association*, 203(3), 201-204.

Creswell, J. W. (2007). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. Thousand Oaks, CA: Sage Publications.

Dcosta, S., & Dey, C. et al. (2022). Effect of Duration of Exercise on VO_2 Max and Endurance. *International Journal of Scientific Study*, 10(1), 21-24.

Dlugosz, E. M. et al. (2013). Phylogenetic Analysis of Mammalian Maximal Oxygen Consumption during Exercise. *Journal of Experimental Biology*, 216(24), 4712-4721.

Fick, A. (1870). Ueber die Messung dea Blutquantums in den Herzventrikela. *Verhandlungen der Physikalisch-medizinische Gesellschaft zu Würzburg*, 2, XVI-XVII.

Fleg, J. L., & Morrell, C. H. et al. (2005). Accelerated Longitudinal Decline of Aerobic Capacity in Healthy Older Adults. *Circulation*, 112(5), 674-682.

Gazibarich, G. J., Boland, J. E., & Louis W. Wang, L. W. (2019). Analysis and Interpretation of Fick and Thermodilution Cardiac Output Determinations (2nd Ed.). *Interventional Cardiology and Cardiac Catheterisation: The Essential Guide*, CRC Press.

Gönülateş, S. (2018). Analysis of Difference between the $\dot{V}O_2max$ Values in Field and Laboratory Tests. *Universal Journal of Educational Research*, 6(9), 1938-1941.

Hale, T. (2008). History of Developments in Sport and Exercise Physiology: A. V. Hill, Maximal Oxygen Uptake, and Oxygen Debt. *Journal of Sports Sciences*. 26(4), 365-400.

Hawkins, S. A., & Wiswell, R. A. (2003). Rate and Mechanism of Maximal Oxygen Consumption Decline with Aging Implications for Exercise Training. *Sports Medicine*, 33(12), 877-888.

Heyward, V. H. (2010). *Advanced Fitness Assessment and Exercise Prescription* (6th Ed.). Human Kinetics, Champaign.

Hill, A. V. (1926). The Scientific Study of Athletics. *Scientific American*, 224(4), 224-225.

Huldani et al. (2020). Differences in $\dot{V}O_2max$ Based on Age, Gender, Hemoglobin Levels, and Leukocyte Count in Hajj Prospective Pilgrims in Hulu Sungai Tengah Regency, South Kalimantan. *Systematic Reviews in Pharmacy*, 11(4), 09-14.

Islam, J. N., Mohajan, H. K., & Moolio, P. (2009a). Preference of Social Choice in Mathematical Economics. *Indus Journal of Management & Social Sciences*, 3(1), 17-38.

Islam, J. N., Mohajan, H. K., & Moolio, P. (2009b). Political Economy and Social Welfare with Voting Procedure. *KASBIT Business Journal*, 2(1), 42-66.

Islam, J. N., Mohajan, H. K., & Moolio, P. (2010). Utility Maximization Subject to Multiple Constraints. *Indus Journal of Management & Social Sciences*, 4(1), 15-29.

Islam, J.N.; Mohajan, H. K., & Moolio, P. (2011), Output Maximization Subject to a Nonlinear Constraint, *KASBIT Business Journal*, 4(2), 104-120.

Islam, J. N., Mohajan, H. K., & Datta, R. (2012a). Aspects of Microfinance System of Grameen Bank of Bangladesh. *International Journal of Economics and Research*, 3(4), 76-96.

Islam, J. N., Mohajan, H. K., & Datta, R. (2012b). Stress Management Policy Analysis: A Preventative Approach. *International Journal of Economics and Research*, 3(6), 1-17.

Islam, J. N., Mohajan, H. K., & Moolio, P. (2012c). Borda Voting is Non-manipulable but Cloning Manipulation is Possible. *International Journal of Development Research and Quantitative Techniques*, 2(1), 28-37.

Klusiewicz, A. et al. (2016). Indirect Methods of Assessing Maximal Oxygen Uptake in Rowers. *Journal of Human Kinetics*, 50, 187-194.

Kodama, S. & Tanaka, S. et al. (2009). Cardiorespiratory Fitness as a Quantitative Predictor of All-Cause Mortality and Cardiovascular Events in Healthy Men and Women: A Meta-Analysis. *JAMA*, 301(19), 2024-2035.

Krogh, A., & Lindhard, J. (1920). The Changes in Respiration at the Transition from Work to Rest. *Journal of Physiology*, 53(6), 431-437.

Lindstedt, S. L., & Hokanson, J. F. et al. (1991). Running Energetics in the Pronghorn Antelope. *Nature*, 353(6346), 748-750.

Little, J. P., Safdar, A., Wilkin, G. P., Tarnopolsky, M. A., & Gibala, M. J. (2010). A Practical Model of Low-Volume High-Intensity Interval Training Induces Mitochondrial Biogenesis in Human Skeletal Muscle: Potential Mechanisms. *Journal of Physiology*, 588(Pt 6), 1011-1022.

Maughan, R. J., & Leiper, J. B. (1983). Aerobic Capacity and Fractional Utilisation of Aerobic Capacity in Elite and Non-Elite Male and Female Marathon Runners. *European Journal of Applied Physiology and Occupational Physiology*, 52(1), 80-87.

McArdle, W. D., Katch, F. I., & Katch, V. L. (2010). *Exercise Physiology: Nutrition, Energy, and Human Performance* (7th Ed.). Lippincott Williams & Wilkins.

Meredith, C. N., & Zackin, M. J. et al. (1987). Body Composition and Aerobic Capacity in Young and Middle-Aged Endurance-Trained Men. *Medicine & Science in Sports & Exercise*, 19(6), 557-563.

Mohajan, D., & Mohajan, H. K. (2022a). Mathematical Analysis of SEIR Model to Prevent COVID-19 Pandemic. *Journal of Economic Development, Environment and People*, 11(4), 5-30.

Mohajan, D., & Mohajan, H. K. (2022b). Utility Maximization Analysis of an Emerging Firm: A Bordered Hessian Approach. *Annals of Spiru Haret University. Economic Series*, 22(4), 292-308.

Mohajan, D., & Mohajan, H. K. (2022c). Sensitivity Analysis among Commodities and Coupons during Utility Maximization. *Frontiers in Management Science*, 1(3), 13-28.

Mohajan, D., & Mohajan, H. K. (2022d). Importance of Total Coupon in Utility Maximization: A Sensitivity Analysis. *Law and Economy*, 1(5), 65-67.

Mohajan, D., & Mohajan, H. K. (2022e). Development of Grounded Theory in Social Sciences: A Qualitative Approach. *Studies in Social Science & Humanities*, 1(5), 13-24.

Mohajan, D., & Mohajan, H. K. (2022f). Exploration of Coding in Qualitative Data Analysis: Grounded Theory Perspective. *Research and Advances in Education*, 1(6), 50-60.

Mohajan, D., & Mohajan, H. K. (2022g). Memo Writing Procedures in Grounded Theory Research Methodology. *Studies in Social Science & Humanities*, 1(4), 10-18.

Mohajan, D., & Mohajan, H. K. (2022h). Constructivist Grounded Theory: A New Research Approach in Social Science. *Research and Advances in Education*, 1(4), 8-16.

Mohajan, D., & Mohajan, H. K. (2022i). Feminism and Feminist Grounded Theory: A Comprehensive Research Analysis. *Journal of Economic Development, Environment and People*, 11(3), 49-61.

Mohajan, D., & Mohajan, H. K. (2022j). Profit Maximization Strategy in an Industry: A Sustainable Procedure. *Law and Economy*, 1(3), 17-43.

Mohajan, D., & Mohajan, H. K. (2023a). Sensitivity Analysis among Commodities and Prices: Utility Maximization Perceptions. *Law and Economy*, 2(2), 1-16.

Mohajan, D., & Mohajan, H. K. (2023b). Straussian Grounded Theory: An Evolved Variant in Qualitative Research. *Studies in Social Science & Humanities*, 2(2), 33-40.

Mohajan, D., & Mohajan, H. K. (2023c). Sensitivity Analysis between Lagrange Multipliers and Consumer Coupon: Utility Maximization Perspective. *Frontiers in Management Science*, 2(1), 14-25.

Mohajan, D., & Mohajan, H. K. (2023d). Utility Maximization Analysis of an Organization: A Mathematical Economic Procedure. *Law and Economy*, 2(1), 1-15.

Mohajan, D., & Mohajan, H. K. (2023e). Classic Grounded Theory: A Qualitative Research on Human Behavior. *Studies in Social Science & Humanities*, 2(1), 1-7.

Mohajan, D., & Mohajan, H. K. (2023f). Sensitivity Analysis between Commodity and Budget: Utility Maximization Case. *Law and Economy*, 2(3), 10-21.

Mohajan, D., & Mohajan, H. K. (2023g). Sensitivity Analysis for Profit Maximization with Respect to Per Unit Cost of Subsidiary Raw Materials. *Frontiers in Management Science*, 2(2), 13-27.

Mohajan, D., & Mohajan, H. K. (2023h). Families of Grounded Theory: A Theoretical Structure for Novel Researchers. *Studies in Social Science & Humanities*, 2(1), 56-65.

Mohajan, D., & Mohajan, H. K. (2023i). Broca Index: A Simple Tool to Measure Ideal Body Weight. *Innovation in Science and Technology*, 2(2), 21–24.

Mohajan, D., & Mohajan, H. K. (2023j). Obesity and Its Related Diseases: A New Escalating Alarming in Global Health. *Journal of Innovations in Medical Research*, 2(3), 12–23.

Mohajan, D., & Mohajan, H. K. (2023k). Body Mass Index (BMI) is a Popular Anthropometric Tool to Measure Obesity among Adults. Unpublished Manuscript.

Mohajan, D., & Mohajan, H. K. (2023*l*). A Study on Body Fat Percentage for Physical Fitness and Prevention of Obesity: A Two Compartment Model. Unpublished Manuscript.

Mohajan, D., & Mohajan, H. K. (2023m). Ponderal Index: An Important Anthropometric Indicator for Physical Growth. Unpublished Manuscript.

Mohajan, D., & Mohajan, H. K. (2023*n*). Economic Situations of Lagrange Multiplier When Cost of Various Inputs Increases for Nonlinear Budget Constraint. *Studies in Social Science & Humanities*, 2(4), 40-64.

Mohajan, D., & Mohajan, H. K. (2023*o*). Glaserian Grounded Theory and Straussian Grounded Theory: Two Standard Qualitative Research Approaches in Social Science. *Journal of Economic Development, Environment and People*, 12(1), 72-81.

Mohajan, D., & Mohajan, H. K. (2023p). Sensitivity Analysis for Utility Maximization: A Study on Lagrange Multipliers and Commodity Coupons. *Journal of Economic Development, Environment, and People*, 12(1), 25-40.

Mohajan, D., & Mohajan, H. K. (2023q). Sensitivity Analysis between Lagrange Multipliers and Consumer Budget: Utility Maximization Case. *Annals of Spiru Haret University. Economic Series*, 23(1), 167-185.

Mohajan, H. K. (2011a). Greenhouse Gas Emissions Increase Global Warming. *International Journal of Economic and Political Integration*, 1(2), 21-34.

Mohajan, H. K. (2011b). The NNP and Sustainability in Open Economy: Highlights on Recent World Economy and on Open Economy of Bangladesh. *KASBIT Business Journal*, 4(2), 32-47.

Mohajan, H. K. (2012a). Green Marketing is a Sustainable Marketing System in the Twenty First Century. *International Journal of Management and Transformation*, 6(2), 23-39.

Mohajan, H. K. (2012b). Aspects of Green Marketing: A Prospect for Bangladesh. *International Journal of Economics and Research*, 3(3), 1-11.

Mohajan, H. K. (2012c). *Importance of Green Marketing at Present and Future*. Lambert Academic Publishing, Germany.

Mohajan, H. K. (2012d). Greenhouse Gas Emissions of the USA. *Indus Journal of Management & Social Sciences*, 6(2), 132-148.

Mohajan, H. K. (2012e). Relation between Lease Finance and Purchase. *International Journal of Economics and Research*, 3(3), 146–158.

Mohajan, H. K. (2012f). Air Pollution Causes Health Effects and Net National Product of a Country Decreases: A Theoretical Framework. *International Journal of Development Research and Quantitative Techniques*, 2(2), 3–10.

Mohajan, H. K. (2013a). Economic Development of Bangladesh. *Journal of Business Management and Administration*, 1(4), 41-48.

Mohajan, H. K. (2013b). Ethiopia: A Socio-economic Study. *Journal of Business Management and Administration*, 1(5), 59-74.

Mohajan, H. K. (2013c). Friedmann, Robertson-Walker (FRW) Models in Cosmology. *Journal of Environmental Treatment Techniques*, 1(3), 158-164.

Mohajan, H. K. (2013d). *Global Greenhouse Gas Emissions and Climate Change*. Lambert Academic Publishing, Germany.

Mohajan, H. K. (2013e). Poverty and Economic Development of Kenya. *International Journal of Information Technology and Business Management*, 18(1), 72-82.

Mohajan, H. K. (2013f). Global Food Price Hike is a Burden to the Poor. *International Journal of Information Technology and Business Management*, 19(1), 1–15.

Mohajan, H. K. (2013g). Food, Agriculture and Economic Situation of Bangladesh. MPRA Paper No. 54240. https://mpra.ub.uni-muenchen.de/54240/

Mohajan, H. K. (2014a). Greenhouse Gas Emissions of China. *Journal of Environmental Treatment Techniques*, 1(4), 190–202.

Mohajan, H. K. (2014b). Chinese Sulphur Dioxide Emissions and Local Environment Pollution. *International Journal of Scientific Research in Knowledge*, 2(6), 265-276.

Mohajan, H. K. (2014c). The Most Fatal 2014 Outbreak of Ebolavirus Disease in Western Africa. *American Journal of Epidemiology and Infectious Disease*, 2(4), 101-108.

Mohajan, H. K. (2014d). Food and Nutrition of Bangladesh. *Peak Journal of Food Science and Technology*, 2(1), 1–17.

Mohajan, H. K. (2014e). Improvement of Health Sector in Kenya. *American Journal of Public Health Research*, 2(4), 159–169.

Mohajan, H. K. (2014f). Gravitational Collapse of a Massive Star and Black Hole Formation. *International Journal of Reciprocal Symmetry & Theoretical Physics*, 1(2), 125–140.

Mohajan, H. K. (2014g). General Upper Limit of the Age of the Universe. *ARPN Journal of Science and Technology*, 4(1), 4–12.

Mohajan, H. K. (2015a). Sustainable Development Policy of Global Economy. *American Journal of Environmental Protection*, 3(1), 12-29.

Mohajan, H. K. (2015b). Present and Future of Nestlé Bangladesh Limited. *American Journal of Food and Nutrition*, 3(2), 34-43.

Mohajan, H. K. (2015c). Basic Concepts of Differential Geometry and Fibre Bundles. *ABC Journal of Advanced Research*, 4(1), 57-73.

Mohajan, H. K. (2015d). Tuberculosis is a Fatal Disease among Some Developing Countries of the World. *American Journal of Infectious Diseases and Microbiology*, 3(1), 18-31.

Mohajan, H. K. (2015e). Generalization of Euler and Ramanujan's Partition Function. *Asian Journal of Applied Science and Engineering*, 4(3), 167–190.

Mohajan, H. K. (2016a). An Analysis of Knowledge Management for the Development of Global Health. *American Journal of Social Sciences*, 4(4), 38-57.

Mohajan, H. K. (2016b). Global Hyperbolicity in Space-time Manifold. *International Journal of Professional Studies*, 1(1), 14-30.

Mohajan, H. K. (2017a). Roles of Communities of Practice for the Development of the Society. *Journal of Economic Development, Environment and People*, 6(3), 27-46.

Mohajan, H. K. (2017b). Two Criteria for Good Measurements in Research: Validity and Reliability. *Annals of Spiru Haret University Economic Series*, 17(3), 58-82.

Mohajan, H. K. (2017c). Optimization Models in Mathematical Economics. *Journal of Scientific Achievements*, 2(5), 30-42.

Mohajan, H. K. (2017d). A Brief Analysis of de Sitter Universe in Relativistic Cosmology. *Journal of Scientific Achievements*, 2(11), 1–17.

Mohajan, H. K. (2017e). Development of Einstein's Static Cosmological Model of the Universe. *Journal of Scientific Achievements*, 2(7), 18–30.

Mohajan, H. K. (2018a). Qualitative Research Methodology in Social Sciences and Related Subjects. *Journal of Economic Development, Environment and People*, 2(1), 19-46.

Mohajan, H. K. (2018b). *Aspects of Mathematical Economics, Social Choice and Game Theory*. PhD Dissertation, Jamal Nazrul Islam Research Centre for Mathematical and Physical Sciences (JNIRCMPS), University of Chittagong, Chittagong, Bangladesh.

Mohajan, H. K. (2018c). The Rohingya Muslims in Myanmar are Victim of Genocide! *ABC Journal of Advanced Research*, 7(1), 59-72.

Mohajan, H. K. (2018d). Medical Errors Must be Reduced for the Welfare of the Global Health Sector. *International Journal of Public Health and Health Systems*, 3(5), 91-101.

Mohajan, H. K. (2018e). Analysis of Food Production and Poverty Reduction of Bangladesh. *Annals of Spiru Haret University Economic Series*, 18(1), 191-205.

Mohajan, H. K. (2020a). Quantitative Research: A Successful Investigation in Natural and Social Sciences. *Journal of Economic Development, Environment and People*, 9(4), 50–79.

Mohajan, H. K. (2020b). COVID-19–The Most Fatal Pandemic Outbreak: An Analysis of Economic Consequences. *Annals of Spiru Haret University Economic Series*, 20(2), 127-146.

Mohajan, H. K. (2020c). The COVID-19 in Italy: Remedies to Reduce the Infections and Deaths. *Malaysian Journal of Medical and Biological Research*, 7(2), 59-66.

Mohajan, H. K. (2020d). Most Fatal Pandemic COVID-19 Outbreak: An Analysis of Economic Consequences. *Annals of Spiru Haret University Economic Series*, 20(2), 127-146.

Mohajan, H. K. (2020e). Circular Economy can Provide a Sustainable Global Society. *Journal of Economic Development, Environment and People*, 9(3), 38–62.

Mohajan, H. K. (2021a). *Aspects of Global COVID-19 Pandemic*. Lambert Academic Publishing, Germany.

Mohajan, H. K. (2021b). Global COVID-19 Pandemic: Prevention and Protection Techniques. *Journal of Economic Development, Environment and People*, 10(1), 51-72.

Mohajan, H. K. (2021c). Estimation of Cost Minimization of Garments Sector by Cobb-Douglass Production Function: Bangladesh Perspective. *Annals of Spiru Haret University. Economic Series*, 21(2), 267-299.

Mohajan, H. K. (2021d). Product Maximization Techniques of a Factory of Bangladesh: A Sustainable Procedure. *American Journal of Economics, Finance and Management*, 5(2), 23-44.

Mohajan, H. K. (2022a). Four Waves of Feminism: A Blessing for Global Humanity. *Studies in Social Science & Humanities*, 1(2), 1-8.

Mohajan, H. K. (2022b). An Overview on the Feminism and Its Categories. *Research and Advances in Education*, 1(3), 11-26.

Mohajan, H. K. (2022c). Cost Minimization Analysis of a Running Firm with Economic Policy. *Annals of Spiru Haret University. Economic Series*, 22(3), 317-337.

Mohajan, H. K. (2022d). Mathematical Analysis of SIR Model for COVID-19 Transmission. *Journal of Innovations in Medical Research*, 1(2), 1-18.

Mohajan, H. K., Datta, R., & Das, A. K. (2012). Emerging Equity Market and Economic Development: Bangladesh Perspective. *International Journal of Economics and Research*, 3(3), 128–145.

Mohajan, H. K., Islam, J. N., & Moolio, P. (2013). *Optimization and Social Welfare in Economics*. Lambert Academic Publishing, Germany.

Moolio, P., Islam, J. N., & Mohajan, H. K. (2009). Output Maximization of an Agency. *Indus Journal of Management and Social Sciences*, 3(1), 39-51.

Moxnes, J. F., & Hausken, K. (2012). Comparing $\dot{V}O_2$max Improvement in Five Training Methods. *Advanced Studies in Theoretical Physics*, 6(19), 931-957.

Myers, J., & Prakash, M. et al. (2002). Exercise Capacity and Mortality among Men Referred for Exercise Testing. *New England Journal of Medicine*, 346(11), 793-801.

Pollock, M. L., Miller, H. S., & Wilmore, J. (1974). Physiological Characteristics of Champion American Track Athletes 40 to 75 Years of Age. *Journals of Gerontology Series: A Biological Sciences and Medical Sciences*, 29(6), 645-649.

Polit, D. F., & Hungler, B. P. (2013). *Essentials of Nursing Research: Methods, Appraisal, and Utilization* (8th Ed.). Philadelphia: Wolters Kluwer/Lippincott Williams and Wilkins.

Pugh, K. G., & Wei, J. Y. (2001). Clinical Implications of Physiological Changes in the Aging Heart. *Drugs & Aging*, 18(4), 263-276.

Rahman, M. M., & Mohajan, H. K. (2019). Rohingya-The Stateless Community Becoming the Lost Generation. *Journal of Economic Development, Environment and People*, 8(2), 24-36.

Roy, L., Molla, R., & Mohajan, H. K. (2021). Cost Minimization is Essential for the Sustainable Development of an Industry: A Mathematical Economic Model Approach. *Annals of Spiru Haret University. Economic Series*, 21(1), 37-69.

Robinson, S. (1938). Experimental Studies of Physical Fitness in Relation to Age. *Arbeitsphysiologie*, 10, 251-323.

Rodrigues, A. N. et al. (2006). Maximum Oxygen Uptake in Adolescents as Measured by Cardiopulmonary Exercise Testing: A Classification Proposal. *Journal of Pediatrics*, 82(6), 426-430.

Rogers, M. A. et al. (1990). Decline in $\dot{V}O_2$max with Aging in Master Athletes and Sedentary Men. *Journal of Applied Physiology*, 68, 2195-2199.

Ross, R. et al. (2016). Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. *Circulation*, 134(24), e653-e699.

Scribbans, T. D. (2016). The Effect of Training Intensity on VO2max in Young Healthy Adults: A Meta-Regression and Meta-Analysis. *International Journal of Exercise Science*, 9(2), 230-247.

Seiler, S. (2011). A Brief History of Endurance Testing in Athletes. *Sportscience*, 15, 40-86.

Smirmaul, B. P., Bertucci, D. R., & Teixeira, I. P. (2013). Is the VO_2max that We Measure Really Maximal? *Frontiers in Physiology*, 4(Article 203), 1-4.

Stringer, W. W. (2010). Cardiopulmonary Exercise Testing: Current Applications. *Expert Review of Respiratory Medicine*, 4(2), 179-188.

Taylor, H. L., Buskirk, E., & Henshel, A. (1955). Maximal Oxygen Intake as an Objective Measure of Cardiorespiratory Performance. *Journal of Applied Physiology*, 8, 73-80.

Wen, D., & Utesch, T. et al. (2019). Effects of Different Protocols of High Intensity Interval Training for $\dot{V}O_2$max Improvements in Adults: A Meta-Analysis of Randomised Controlled Trials. *Journal of Science and Medicine in Sport*, 22(8), 941-947.

Woo, J. S., Derleth, C., Stratton, J. R., & Levy, W. C. (2006). The Influence of Age, Gender, and Training on Exercise Efficiency. *Journal of the American College of Cardiology*, 47(5), 1049-1057.