Chapter

Importance of Resistance Training in the Management of Cardiovascular Disease Risk

Brandon S. Shaw, Gregory A. Brown and Ina Shaw

Abstract

Contrary to the longstanding taboo of resistance training (RT) as a therapeutic treatment, RT has been gaining importance as a safe therapeutic option in the management of numerous diseases. Although exercise has well-documented health benefits on cardiovascular disease (CVD), the benefit of RT on CVD risk factors is not yet as widely prescribed as other modes of exercise. Due to its efficacy in the management of CVD, RT should be regarded as a complementary therapeutic treatment rather than a substitute to other modes of exercise therapy. While it is clear that RT can result in an attenuation of CVD risk, the various RT design options related to intensity and volume and how they impact on CVD risk, especially in different populations (i.e. children, elderly, women) is not yet well documented. This chapter will discuss the physiological phenomenon and benefits of RT as a therapeutic intervention aiming to manage CVD risk.

Keywords: CVD Management, CVD Prevention, Resistance Exercise Prescription, Strength Training, Weight Training

1. Introduction

Cardiovascular disease (CVD) is the number one cause of death worldwide [1]. It includes diseases of the heart, blood vessels supplying the heart, brain, and other organs [2] and includes diseases such as angina, myocardial infarction (MI) (heart attack), cerebrovascular attacks (stroke), heart failure, cardiomyopathy, carditis, abnormal heart rhythms, congenital heart disease, rheumatic heart disease, valvular heart disease, hypertensive heart disease, aortic aneurysms, peripheral artery disease, thromboembolic disease and venous thrombosis [3].

The underlying cause of CVD varies depending on the disease and may be caused by a variety of factors [4]. These risk factors for developing CVD are traditionally divided into primary and secondary risk factors with primary risk factors being those risk factors that have conclusively shown to have a strong association with CVD. In this regard, smoking, hypertension, dyslipidemia and physical inactivity, are the four traditional primary risk factors [5]. On the other hand, secondary risk factors include diabetes mellitus, obesity, diet, psychological factors, age, hereditary/family history, gender, ethnicity/race, and personal (previous) history [5]. Thankfully, CVD risk factors can be classified into modifiable and non-modifiable risk factors. Of particular importance to healthcare practitioners are the modifiable CVD risk factors, since these factors can be impacted upon via various interventions [1, 4].

Although physical inactivity or a sedentary lifestyle is one of the major risk factors for developing CVD, physical activity has proved especially useful in the overall prevention and treatment of CVD [4]. Problematically, despite strong scientific evidence supporting the benefits of regular physical activity for the prevention and management of CVD, physical inactivity is highly prevalent worldwide.

In addition, while it is known that physical activity is a critical intervention in the prevention and management of CVD, numerous types of modalities of physical activity exist. This includes, amongst others, aerobic exercise including walking, jogging, swimming, skipping rope, muscular fitness training including, strength training, power training, hypertrophy training, muscle endurance training, flexibility exercises, balance exercises, martial arts, and other physical fitness systems, including Pilates, Yoga and CrossFit. This sheer diversity of physical activity and the various variables of exercise programme design, which are exercise selection, intensity, repetitions, tempo, rest interval, sets and frequency of exercise sessions further complicate our understanding of what physical activity actually works or is best for the prevention and management of CVD in general, or for a specific type of CVD [4].

1.1 Health benefits of physical activity

Regular physical activity has an ancient association with general health and today it is unquestionable by all those involved in healthcare that regular physical activity provides many physical and psychological benefits. In this regard, >100,000 studies demonstrate positive associations between exercise and health [6]. In fact, overwhelming evidence exists that regular physical activity is associated with delaying the onset of 40 chronic conditions/diseases [7]. As such, exercise has proven to be a critical medical intervention even in diseases with a non-locomotor component. Specifically, a significant amount of scientific evidence has established a causal relationship between non-communicable diseases (NCD) and physical activity. This is especially important in that NCDs, such as CVD, diabetes and cancer, cause 65% of all deaths worldwide and are projected to result in >75% of all deaths by 2030 [8].

The success of physical activity in preventing, delaying and rehabilitating a multitude of chronic conditions/diseases relates to physical activity's multisystem responses. While the benefits of physical activity have been attributed to several mechanisms, including improved blood hemodynamics [9], improved levels of circulating lipids [10], increased cardiorespiratory fitness (CRF) [11, 12] and a reduced adiposity and enhanced muscle mass [13], more recent research has shown that during physical activity, proteins, peptides, enzymes and metabolites are released from one organ (mainly contracting skeletal muscle) to affect the metabolism in another organ [14].

1.2 Physical activity and CVD

Regular physical activity has a long scientific association with a reduced risk of CVD [15]. Two of the most well-known such studies demonstrating the importance of physical activity in preventing CVD are the Framingham Heart Study and London Transport Workers Study.

Prior to the Framingham Heart Study began in 1948 in Framingham, Massachusetts, little was known about the epidemiology of CVD. However, that study demonstrated much of the now-common knowledge concerning CVD, such as the effects of physical activity on CVD. In fact, the Framingham Heart Study is the source of the term risk factor [16]. The London Transport Workers Study, published in 1953 by Jeremy N. Morris was the first rigorous epidemiological study investigating physical activity and CVD risk. In that study, drivers and conductors of the London Transport Executive were compared and CVD rates were found to be increased in physically inactive bus drivers versus active conductors [17, 18].

More recently, many leading international organisations have recognised the importance of physical activity as medicine in not only improving health, but also preventing and managing CVD and have issued calls to action to make physical activity a priority in this regard [19, 20].

In addition to its independent effects on traditional CVD risk factors, regular physical activity can also improve cardiovascular health and impact upon non-traditional or novel CVD risk factors, such as C-reactive protein and oxidative stress [21, 22]. Physical activities' effectiveness at preventing and managing CVD is due to its ability to target various pathways through which it influences different physiological systems, such as its ability to promote a healthy anti-inflammatory environment, largely through the release of muscle-derived myokines, its ability to stimulate myocardial regeneration and its ability to improve age-related loss of muscle mass and strength, a frequently overlooked non-traditional CVD risk factor [23–25].

What is particularly noteworthy about physical activity's role in CVD prevention and management are the findings that even a single session or brief periods of physical activity are known to be associated with improvements in cardiovascular health parameters [26], such as an immediate decrease in blood pressure, also called post-exercise hypotension (PEH) [27], improved blood levels of lipids [28], enhanced fat oxidation [29] and improved insulin sensitivity [30].

1.3 Health benefits of resistance training (RT)

While it is still argued that cardiorespiratory fitness (CRF) is the most important measure for health, numerous other primary health-related physical fitness parameters exist and include; musculoskeletal fitness, body composition and flexibility [31]. Not only does resistance training (RT) improve on these parameters, but RT has also shown to enhance several other important aspects of physical and mental health [32]. Further, RT has also been associated with reduced low back pain, decreased arthritic discomfort, increased functional independence, improved mobility, enhanced functional status, enhanced movement control, and increased walking speed [32, 33]. What is especially important to note is that RT is equally, and in some cases superior, to other modes of physical activity, such as aerobic training, in its health-promoting benefits. Examples of this are RT's superior ability to increase metabolic rate, lean body mass and bone mineral density [33]. It is for these reasons that RT is recommended by numerous health organisations (e.g., American College of Sports Medicine, American Heart Association, American Association of Cardiovascular and Cardiopulmonary Rehabilitation, Surgeon General's Office) for inclusion into a comprehensive fitness programme that includes aerobic and flexibility exercise [34].

1.4 Resistance training and prevention and management of cardiovascular disease (CVD)

It is explicit that RT has been recognised for its value in improving the health of athletes and the general public. However, only recently has scientific evidence emerged substantiating its benefits in the prevention and management of CVD [35]. This is especially true given RT's unique benefits over other modes of physical activity, especially improving the often overlooked non-traditional CVD risk factors of muscle mass and strength loss [23–25].

The evidence for a blood pressure-lowering effect of RT remains scarce [36]. However, when such evidence is forthcoming it provides confirmation for the potential of RT in the prevention and treatment of high blood pressure in normo- and even hypertensive patients [37, 38]. Additionally, some studies even demonstrate that RT is equally or more effective than aerobic training at doing so [39]. What is especially important to note is that little/no RT studies have reported serious adverse events in even hypertensive participants [36].

A reduction in cholesterol levels are considered the gold standard in preventative cardiovascular medicine [40]. This is why it is essential that much evidence supports the role that RT improves HDL-cholesterol whilst reducing total cholesterol, LDL-cholesterol and triglycerides in adults [41–43]. What is particularly interesting is that RT shows a stronger association than aerobic exercise when attempting to improve HDL-cholesterol [44, 45]. It appears that an increased volume (via increased numbers of sets or repetitions), rather than intensity or load, has a greater impact on lipid profiles [46].

While CRF improvements following RT are not as substantial as those following a period of aerobic training [47], the evidence that RT does indeed increase CRF [36] is critical, since an enhanced CRF is associated with a lower risk of all-cause mortality and cardiovascular events [48]. Interestingly, both low- and high-intensity RT have demonstrated to improve CRF, albeit via different proposed mechanisms, such as an increased Type IIa muscle activity, increases in leg strength (i.e. for pedal thrust and efficiency of movement), improvements in oxidative enzymes [49]. However, many of the CRF adaptations to RT appear to be dependent on a higher volume of training [50].

More than 39% (1.9 billion) of adults were found to be overweight and 13% (650 million) obese in 2016 [51]. This is in addition to over 340 million children and adolescents being found to be overweight or obese in 2016 [51]. This is problematic in that overweight and obesity are associated with an increased incidence of various CVDs, such as diabetes, hypertension, and metabolic syndrome [52]. It is this CVD risk factor in which the effect of RT on body composition is unique when compared to other modes of physical activity. Specifically, RT has the ability to increase muscle mass, while simultaneously reducing fat mass [33, 53]. Further, RT offers an alternative to other modes of physical activity that may not be tolerated as well by individuals who are already overweight or obese, due to the excess body weight increasing the intensity (and perceived exertion) of weight-bearing activity [54, 55]. Another reason or barrier limiting participation in aerobic-type activities may arise from an initially low CRF [54, 56].

The increasing prevalence of diabetes suggests a clear need for effective diabetes prevention and management approaches [57, 58]. As stated previously, RT is unique in its ability to prevent overweight and obesity and it is for this reason that RT is receiving increasing recognition as a cornerstone in the prevention and treatment of type 2 diabetes [59, 60]. In this regard, emerging research suggests that RT has the power to combat metabolic dysfunction in patients with type 2 diabetes. Some of the beneficial adaptations exerted by RT include increased GLUT4 translocation in skeletal muscle, increased insulin sensitivity and restored metabolic flexibility. Further, an increased energy expenditure and excess post-exercise oxygen consumption (EPOC) in response to RT may be other beneficial effects [60]. In fact, it appears that RT can improve glycemic control and insulin sensitivity likely even more than aerobic training [61, 62].

Epidemiological studies have demonstrated the role of diet as a secondary CVD risk factor, as it has an important role to play in other CVD risk factors, such as hypertension, dyslipidemia, diabetes and obesity [63]. The role of diet in CVD development is complex and involves many dietary factors, including *inter alia* an excessive dietary intake of fat (particularly saturated fat), excessive intake of cholesterol, high intakes of certain carbohydrates (i.e. fructose and sucrose), excessive salt intake, excessive alcohol consumption and an inadequate intake of fiber [64]. Although research on the effects of RT on dietary patterns and intake is limited, most studies demonstrate that RT is unable to alter self-selected food intake or food preference [64–67]. However, cross-sectional studies do exist that demonstrate athletes engaging in RT have a decreased dietary intake of fat, even when compared to aerobic athletes [68]. While it seems RT may have no effect on dietary preferences, RT may affect diet indirectly by offsetting the effects of a poor diet. In this regard, since RT increases nitrogen retention, enhances protein synthesis and improves the expression of insulin-like growth factor in skeletal muscle, the anabolic potential of RT is useful in counteracting the catabolism experienced during CVD, such as interleukin-mediated myopathy of chronic heart failure, myopathy secondary to corticosteroid use in cardiac transplantation and during energy restriction for obesity management [69].

Much evidence exists identifying the mechanisms by which psychological factors, such as stress, depression, and anxiety and impact CVD [70]. In addition to RT's numerous physical benefits, the effect of RT on psychological factors is well documented. In this regard, the demonstrated mental health benefits of RT include decreased symptoms of depression, increased self-esteem, increased self-efficacy, increased, physical self-concept, improved cognitive ability and enhanced social interaction [71–73]. Specifically relating to CVD, it appears that RT may provide unique psychological benefits when compared to other physical activity modalities. This is because psychological benefits may be more related to reductions in body fat than changes in strength or fitness [72, 73]. Therefore, RT could be an alternative to aerobic training for some individuals in the biological and psychological management of adolescent obesity [72, 73].

1.5 Safety of resistance training in the management of cardiovascular disease risk

Resistance training is an exercise modality that can potentially target many of the adverse effects of CVD. However, there have been concerns regarding the safety of strenuous RT and its application to existing and future clinical interventions.

In the past, RT has been regarded as hazardous due to inflated blood pressure responses, elevated double pressure products and an increase in ischemic events. However, more recent research has demonstrated that RT may be less risky than was once assumed. In this regard, previous research has established intra-arterial blood pressures during RT in cardiac patients to be within a clinically tolerable range at 40–60% of 1-RM [72, 73]. Further, research has also demonstrated that electrocardiographic (ECG) responses during RT at 20%, 40%, 60%, and 80% of 1-RM failed to induce clinically significant ST-segment depression, angina or ventricular arrhythmias [74]. In fact, RT has not been found elicit significant cardiovascular events even during 1-RM determination [75]. As such, light-to-moderate RT can be deemed safe for low- to moderate-risk CVD patients.

With regards to the use of RT in high-risk CVD patients, even though traditional RT participation guidelines have previously advised that surgical and post–myocardial infarction (MI) patients should avoid RT for at least four to six months [76], it has been demonstrated that these patients can safely complete static-dynamic activity corresponding to carrying up to 30 pounds or about 13 kilogrammes by three weeks after an acute MI [77]. As such, it is probable that RT could be introduced earlier in even these high-risk settings should low-load programmes be prescribed.

While moderate to good left ventricular function and cardiorespiratory fitness in the absence of anginal symptoms or ischemic ST-segment depression have been proposed as preconditions for participation in RT, contraindications to RT comprise unstable angina, uncontrolled hypertension (systolic blood pressure ≥ 160 mm/Hg and/or diastolic blood pressure ≥ 100 mm/Hg), uncontrolled dysrhythmias, recent history of congestive heart failure that has not been evaluated and effectively treated, severe stenotic or regurgitant valvular disease and hypertrophic cardiomyopathy [78].

1.6 Non-communicable disease intervention research unit (NCDIRU) resistance training guidelines for the prevention and management of CVD

Although RT is increasingly recommended as an integral component of an overall CVD prevention and management programme, many global guidelines impose specific RT programme design recommendations for each CVD risk, type of disease, even at each severity level, or fail to provide specific criteria for training progression [79]. Further, a significant barrier to increased implementation of RT as a clinical therapy is the complex, difficult-to-follow regimes compulsively focusing on design variables such as load, intensity and volume. As such, a more feasible and easier-to-adhere-to paradigm for RT should be explored and adopted as a prescription for public health [80, 81].

In this regard, for apparently healthy individuals or those at low-risk, the Non-Communicable Disease Intervention Research Unit (NCDIRU) recommends utilising 8–10 different RT exercises that train the major muscle groups, with multiple sets (i.e. 3–4 sets) of 8–12 repetitions, with minimal rest intervals (i.e. 30–60 seconds) for most days of a week.

In turn, the NCDIRU recommends that individuals with high-risk should utilise 8–10 different RT exercises that train the major muscle groups using multiple sets (i.e. 3 sets) of 10–12 repetitions, with moderate-long rest intervals (i.e. 60–90 seconds) for 3 days weekly. These high-risk individuals should also have increased patient monitoring and programme supervision when compared to low-risk patients.

Despite much overlap and impracticality, many international organisations have guidelines or position statements for each CVD. However, in an effort to develop a practical and easy-to-follow RT regime that will increase adherence and outcomes, the NCDIRU recommends the following for those patients with existing CVD to delay progression or assist in the management of CVDs: an RT prescription of 8–10 different exercises that train the major muscle groups using 1–2 sets of 10–15 repetitions, twice weekly. In this existing CVD group, exercise sessions should begin at a lower intensity level of 12–15 repetitions and progress more slowly than programmes designed for low-risk patients, allowing time for adaptation. These patients should also have the most patient monitoring and programme supervision. Further, variable resistance machines with selectorised weight stacks should be utilised. In this regard, variable resistance machines with selectorised weight stacks; (1) allow the initial weight applied to be at a low level and increased in small increments; (2) the equipment is usually designed to protect the lower back, thus reducing the risk of injury; (3) many machines are designed to avoid handgripping which reduces the risk of exercise-induced hypertension; (4) the machines are usually designed to allow the resistance to be applied evenly through the patients' full range of motion (ROM); (5) many types of equipment can be double pinned to allow the individual to exercise through their pain-free ROM and 6) many machines do not require the individual to balance or control the weight, as do dumbbells and barbells, which may reduce the likelihood of injury [82].

2. Conclusions

Despite the well-known benefits of exercise, most adults and many children lead relatively sedentary lifestyles and are not active enough to achieve the health benefits of exercise. Further, due to the stigma associated with RT (i.e. erroneous/unfounded issues related to safety and damage to growth plates), many children and adults fail to engage in RT as part of their overall health and prevention/management of CVD [83]. This is despite the accumulating and overwhelming evidence for health and CVD-protective effects of RT. Given its whole-body, health-promoting nature, the integrative responses to RT will continue to attract special interest as the notion of "exercise is medicine" continues its integration into clinical settings [6]. Given that RT has both direct and indirect effects on the mortality and morbidity of CVDs via its identified risk factors (e.g. hypertension, dyslipidemia, obesity and diabetes), health care professionals and health policy makers should incorporate RT advocacy in their daily clinical practice and public health policies.

Acknowledgements

The authors would like to acknowledge the contributions made by the Non-Communicable Disease Intervention Research Unit (NCDIRU).

Conflict of interest

The authors declare no conflict of interest.

Author details

Brandon S. Shaw[1*], Gregory A. Brown[2] and Ina Shaw[1]

1 Department of Human Movement Science, University of Zululand, Kwadlangezwa, South Africa

2 Physical Activity and Wellness Laboratory, Department of Kinesiology and Sports Science, University of Nebraska Kearney, NE, United States of America

*Address all correspondence to: shawb@unizulu.ac.za

References

[1] World Health Organization (WHO). Cardiovascular Diseases (CVDs). 2017. Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)#:~:text=CVDs%20are%20the%20number%201%20cause%20of%20death,deaths%20take%20place%20in%20low-%20and%20middle-income%20countries [Accessed 04/06/2021].

[2] Gaziano T, Reddy KS, Paccaud F, Horton S, Chaturvedi V. Chapter 33: Cardiovascular Disease. In: Jamison DT, Breman JG, Measham AR, Alleyne G, Claeson M, Evans DB, Jha P, Mills A, Musgrove P, editors. Disease Control Priorities in Developing Countries. 2nd ed. Washington (DC): The International Bank for Reconstruction and Development/The World Bank; 2006. ISBN-10: 0-8213-6179-1.

[3] Shaw I, Shaw BS, Brown GA, Cilliers JF. Concurrent Resistance and Aerobic Training as Protection against Heart Disease. Cardiovascular Journal of Africa. 2010;21(4):224-227.

[4] Shaw, B.S. & Shaw, I. Resistance Training as a Countermeasure for Key Non-Communicable Diseases in Low-Resource Settings: A Review. Asian Journal of Sports Medicine. 2021;2(1):1-8, e106588. DOI: 10.5812/asjsm.106588.

[5] Lawrence, K.E., Shaw, I. & Shaw, B.S. Hemodynamic Changes in Normotensive Overweight and Obese Individuals Following Home-Based Calisthenics Training. African Journal for Physical, Health Education, Recreation and Dance. 2014;Supplement 2:82-90.

[6] Ruegsegger GN, Booth FW. Health Benefits of Exercise, In: Zierath JR, Joyner MJ, Hawley JA, editors. Additional Perspectives on the Biology of Exercise. Cold Spring Harbor Laboratory Press; 2018. DOI: 10.1101/cshperspect.a029694.

[7] Booth FW, Roberts CK, Laye MJ. 2012. Lack of Exercise is a Major Cause of Chronic Diseases. Comprehensive Physiology. 2012;2:1143-1211. DOI: 10.1002/cphy.c110025.

[8] Blair SN, Sallis RE, Hutber A, Archer E. Exercise Therapy – The Public Health Message. Scandinavian Journal of Medicine & Science in Sports. 2012;22(4):e24-e28. DOI: 10.1111/j.1600-0838.2012.01462.x.

[9] Pal S, Radavelli-Bagatini S, Ho S. Potential Benefits of Exercise on Blood Pressure and Vascular Function. Journal of the American Society of Hypertension. 2013;7(6):494-506. DOI: 10.1016/j.jash.2013.07.004

[10] Vella CA, Kravitz L, Janot JM. A Review of the Impact of Exercise on Cholesterol Levels. IDEA Health & Fitness Source. 2001;19(10):48.

[11] Kokkinos P, Myers J, Franklin B, Narayan P, Lavie CJ, Faselis C. Cardiorespiratory Fitness and Health Outcomes: A Call to Standardize Fitness Categories. Mayo Clinic Proceedings. 2018;93(3):333-336. DOI: 10.1016/j.mayocp.2017.10.011.

[12] Shaw BS, Shaw I. Chapter 3. Role of Aerobic Exercise. In Cardiopulmonary Health and Rehabilitation. In: Simmons JA, Brown AC, editors. Aerobic Exercise: Health Benefits, Types and Common Misconceptions. Nova Science Publishers, Hauppauge, NY. USA. 2013; p. 59-84. ISBN: 978-1-62618-578-4.

[13] Shaw, I. & Shaw, B.S. (2014). Resistance Training and the Prevention of Sports Injuries. In: Hopkins, G, editors. Sports Injuries: Prevention, Management and Risk Factors. Nova

Science Publishers, Hauppauge, NY. USA. 2014. p. 123-136. ISBN: 978-1-63463-305-5.

[14] Febbraio MA. Health Benefits of Exercise — More than Meets the Eye! Nature Reviews Endocrinology, 2017;13:72-74. DOI: 10.1038/nrendo.2016.218.

[15] Schroeder EC, Franke WD, Sharp RL, Lee D. Comparative Effectiveness of Aerobic, Resistance, and Combined Training on Cardiovascular Disease Risk Factors: A Randomized Controlled Trial. PloS one. 2019;14(1):e0210292. DOI: 10.1371/journal.pone.0210292.

[16] Levy M, Wang V. The Framingham Heart Study and the Epidemiology of Cardiovascular Disease: A Historical Perspective. Lancet. 2013;383 (9921):999-1008. DOI: 10.1016/S0140-6736(13)61752-3.

[17] Morris, J.N., Heady, J.A., Raffle, P.A.B., Roberts, C.G., and Parks, J.W., 1953. Coronary heart disease and physical activity of work. Lancet 265, 1111-1120. DOI: 10.1016/S0140-6736(53)91495-0.

[18] Morris, J.N., Heady, J.A., Raffle, P.A.B., Roberts, C.G., and Parks, J.W., 1953. Coronary heart disease and physical activity of work. Lancet 265, 1053-1057. DOI: 10.1016/S0140-6736 (53)90665-5.

[19] Beaglehole R, Bonita R, Alleyne G, Horton R, Li L, Lincoln P, Mbanya JC, McKee M, Moodie R, Nishtar S, Piot P, Reddy KS, Stuckler D. UN High-Level Meeting on Non-Communicable Diseases: Addressing Four Questions. Lancet. 2011;378: 449-455. DOI: 10.1016/S0140-6736(11)60879-9.

[20] World Health Organization (WHO). 2020. WHO Guidelines on Physical Activity and Sedentary Behaviour. Geneva: World Health Organization. https://www.who.int/publications/i/item/9789240015128. ISBN 978-92-4-001512-8. [Accessed 23/05/2021].

[21] Afzalpour ME, Bashafaat H, Shariat A, Sadeghi H, Shaw I, Dashtiyan AA, Shaw BS. Plasma protein carbonyl responses to anaerobic exercise in female cyclists. International Journal of Applied Exercise Physiology. 2016;5(1): March.

[22] Oliveira e Silva VR, Stringuetta Belik F, Hueb JC, de Souza Gonçalves R, Costa Teixeira Caramori J, Perez Vogt B, Barretti P, Zanati Bazan SG, De Stefano GMM, Martin LC, da Silva Franco RJ. Aerobic Exercise Training and Nontraditional Cardiovascular Risk Factors in Hemodialysis Patients: Results from a Prospective Randomized Trial. 2019;9(6):391-399. DOI: 10.1159/000501589.

[23] Fiuza-Luces C, Santos-Lozano A, Joyner M, Carrera-Bastos P, Picazo O, Zugaza JL, Izquierdo M, Ruilope LM, Lucia A. Exercise Benefits in Cardiovascular Disease: Beyond Attenuation of Traditional Risk Factors. Nature Reviews Cardiology. 2018;15:731-743. DOI: 10.1038/s41569-018-0065-1.

[24] Shaw BS, Shaw I, Brown GA. Resistance Training and its Effect on Total, Central and Abdominal Adiposity. South African Journal for Research in Sport, Physical Education and Recreation. 2009;31(2):97-108. DOI: 10.4314/sajrs.v31i2.46331.

[25] Shaw BS, Shaw I, Mamen A. Contrasting Effects in Body Composition Following Endurance, Resistance and Concurrent Endurance and Resistance Training. Journal of Sports Medicine and Physical Fitness. 2010;50(2):207-213.

[26] Shaw BS, Dullabh M, Forbes G, Brandkamp J, Shaw I. Analysis of Physiological Determinants during a

Single Bout of Crossfit. International Journal of Performance Analysis in Sport. 2015;15:809-815. DOI: 10.1080/24748668.2015.11868832.

[27] Kleinnibbelink G, Stens NA, Fornasiero A, Speretta GF, Van Dijk APJ, Low DA, Oxborough DL, Thijssen DHJ. The Acute and Chronic Effects of High-Intensity Exercise in Hypoxia on Blood Pressure and Post-Exercise Hypotension: A Randomized Cross-Over Trial. Medicine. 2020;25;99 (39):e22411. DOI: 10.1097/MD.0000 000000022411.

[28] Lira FS, Zanchi NE, Lima-Silva AE, Pires FO, Bertuzzi RC, Santos RV, Caperuto EC, Kiss MA, Seelaender M. Acute High-Intensity Exercise with Low Energy Expenditure Reduced LDL-C and Total Cholesterol in Men. European Journal of Applied Physiology. 2009;107:203-210. DOI: 10.1007/s00421-009-1115-5.

[29] Pearson RC, Olenick AA, Green ES, Jenkins NT. Acute Exercise Effects on Postprandial Fat Oxidation: Meta-Analysis and Systematic Review. Applied Physiology, Nutrition, and Metabolism. 2020;45(10):1081-1091. DOI: 10.1139/apnm-2019-0917.

[30] Henriksen EJ. Insulin resistance Effects of Acute exercise and exercise training on insulin resistance. Journal of Applied Physiology. 2002;93(2):788-796. DOI: 10.1152/japplphysiol. 01219.2001.

[31] Sener U, Ucok K, Ulasli AM, Genc A, Karabacak H, Coban NF, Simsek H, Cevik H. Evaluation of Health-Related Physical Fitness Parameters and Association Analysis with Depression, Anxiety, and Quality of Life in Patients with Fibromyalgia. International Journal of Rheumatic Diseases. 2016;19(8):763-772. DOI: 10.1111/1756-185X.12237.

[32] Westcott WL, Resistance Training is Medicine - Effects of Strength Training on Health. Current Sports Medicine Reports. 2012;11(4):209-216. DOI: 10.1249/JSR.0b013e31825dabb8

[33] Shaw BS, Shaw I, Brown GA. Resistance exercise is medicine: Strength training in health promotion and rehabilitation. International Journal of Therapy and Rehabilitation. 2015;22(8):385-389. DOI: 10.12968/ijtr.2015.22.8.385.

[34] Kraemer WJ, Ratamess NA, French DN. Resistance Training for Health and Performance. Current Sports Medicine Reports. 2002;1:165-171 (). DOI: 10.1007/s11932-002-0017-7

[35] Graves JE, Franklin BA. Resistance Training for Health and Rehabilitation. Champaign, Ill: Human Kinetics; 2001. ISBN: 0736001786.

[36] Cornelissen VA, Fagard RF, Coeckelberghs E, Vanhees L. Impact of Resistance Training on Blood Pressure and Other Cardiovascular Risk Factors: A Meta-Analysis of Randomized, Controlled Trials. Hypertension. 2011;58:950-958. DOI: 10.1161/HYPERTENSIONAHA.111.177071.

[37] Cornelissen VA, Smart NA. Exercise Training for Blood Pressure: A Systematic Review and Meta-analysis. Journal of the American Heart Association. 2013;2(1):e004473. DOI: 10.1161/JAHA.112.004473.

[38] Fagard RH. Exercise is Good for your Blood Pressure: Effects of Endurance Training and Resistance Training. Clinical and Experimental Pharmacology and Physiology. 2006;33:853-856. DOI: 10.1111/j.1440-1681.2006.04453.x.

[39] Shaw I, Shaw BS. Effects of Aerobic, Resistance and Combination Exercise Training on Resting Blood Pressure: A Comparative Study. African Journal for Physical, Health Education, Recreation

and Dance. 2006;12(4):384-393. DOI: 10.4314/ajpherd.v12i4.24762.

[40] Mann S, Beedie C, Jimenez A. Differential Effects of Aerobic Exercise, Resistance Training and Combined Exercise Modalities on Cholesterol and the Lipid Profile: Review, Synthesis and Recommendations. Sports Medicine. 2014;44:211-221. DOI: 10.1007/s40279-013-0110-5.

[41] Kelley GA, Kelley KS. Impact of Progressive RT on Lipids and Lipoproteins in Adults: A Meta-Analysis of Randomized Controlled Trials. Preventative Medicine. 2009;48:9-19. DOI: 10.1016/j.ypmed.2008.10.010.

[42] Shaw BS, Shaw I, Goon DT. Resistance Training and Blood Lipid Regulation: A Review of the Evidence. Medicina Dello Sport. 2011;64(4): 511-521.

[43] Shaw I, Shaw BS. Relationship between Resistance Training and Lipoprotein Profiles in Sedentary Male Smokers. Cardiovascular Journal of Africa. 2008;19(4):194-197.

[44] Hsu C, Chang S, Nfor ON, Lee K, Lee S, Liaw Y. Effects of Regular Aerobic Exercise and Resistance Training on High-Density Lipoprotein Cholesterol Levels in Taiwanese Adults. International Journal of Environmental Research and Public Health. 2019; 16:2003. DOI: 10.3390/ijerph16112003.

[45] Shaw BS, Shaw I. Physical Activity and High-Density Lipoprotein Cholesterol in Sedentary Male Smokers. African Journal for Physical, Health Education, Recreation and Dance. 2007;13(4):441-452.

[46] Lira F, Yamashita A, Uchida M, Zanchi NE, Gualano B, Martins Jr E, Caperuto EC, Seelaender M. Low and moderate, rather than high intensity strength exercise induces benefit regarding plasma lipid profile. Diabetology & Metabolic Syndrome. 2010;2:31. doi:10.1186/1758-5996-2-31.

[47] Shaw BS, Shaw I. Effect of Resistance Training on Cardiorespiratory Endurance and Coronary Artery Disease Risk. Cardiovascular Journal of South Africa. 2005;16(5):200-204.

[48] Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, Sugawara A, Totsuka K, Shimano H, Ohashi Y, Yamada N, Sone H. Cardiorespiratory Fitness as a Quantitative Predictor of All-Cause Mortality and Cardiovascular Events in Healthy Men and Women. JAMA. 2009;301:2024. DOI: 10.1001/jama.2009.681.

[49] Staron RS, Leonardi MJ, Karapondo DL, Malicky ES, Falkel JE, Hagerman FC, Hikida RS. Skeletal Muscle Adaptations during Early Phase of Resistance Training in Men and Women. Journal of Applied Physiology. 199;76:1247-1255. DOI: 10.1152/jappl.1994.76.3.1247.

[50] Bishop D, Jenkins DG, Mackinnon LT, Mceniery M, Carey MF. The Effects of Strength Training on Endurance Performance and Muscle Characteristics. Medicine & Science in Sports & Exercise. 1999;31(6):886-891. DOI: 10.1097/00005768-199906000-00018.

[51] World Health Organization (WHO). Obesity and Overweight. 2020. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. [Accessed 12/05/2021].

[52] Mandviwala T, Khalid U, Deswal A. Obesity and Cardiovascular Disease: A Risk Factor or a Risk Marker? Current Atherosclerosis Reports. 2016;18(5):21. DOI: 10.1007/s11883-016-0575-4.

[53] Shaw I, Shaw BS. Consequence of Resistance Training on Body Composition and Coronary Artery

Disease Risk. Cardiovascular Journal of South Africa. 2006;17(3):19-24.

[54] Dietz P, Hoffmann S, Lachtermann E, Simon P. Influence of Exclusive Resistance Training on Body Composition and Cardiovascular Risk Factors in Overweight or Obese Children: A Systematic Review. Obesity Facts. 2012;5:546-560. DOI: 10.1159/000341560

[55] McGuigan M, Tatasciore M, Newton R, Pettigrew S. Eight Weeks of Resistance Training Can Significantly Alter Body Composition in Children Who Are Overweight or Obese. Journal of Strength and Conditioning Research. 2009;23(1):80-85. DOI: 10.1519/JSC.0b013e3181876a56.

[56] Shaw BS, Shaw I. Determinants of Physical Activity in Children and Adolescents: Implications for the Increasing Prevalence of Childhood Obesity. African Journal for Physical, Health Education, Recreation and Dance. 2014;2:91-101.

[57] Flack KD, Davy KP, Hulver MW, Winett RA, Frisard MI, Davy BM. Aging, Resistance Training, and Diabetes Prevention. Journal of Aging Research. 2011:1-2. DOI: 10.4061/2011/127315

[58] Amati F, Dubé JJ, Coen PM, Stefanovic-Racic M, Toledo FGS, Goodpaster BH. Physical Inactivity and Obesity Underlie the Insulin Resistance of Aging. Diabetes Care. 2009;32(8):1547-1549. DOI: 10.2337/dc09-0267.

[59] Shaw BS, Shaw I. Exercise Therapy and its Role in Glucose Maintenance. African Journal for Physical, Health Education, Recreation and Dance. 2008;14(4):417-427. DOI: 10.4314/ajpherd.v14i4.24817.

[60] Strasser B, Pesta D. Resistance Training for Diabetes Prevention and Therapy: Experimental Findings and Molecular Mechanisms. BioMed Research International. 2013. DOI: 10.1155/2013/805217.

[61] Bacchi C, Negri ME, Zanolin, Milanese C, Faccioli N, Trombetta M, Zoppini G, Cevese A, Bonadonna RC, Schena F, Bonora E, Lanza M, Moghetti P. Metabolic Effects of Aerobic Training and Resistance Training in Type 2 Diabetic Subjects. A Randomized Controlled Trial (the READ2 Study). Diabetes Care. 2012;35:676-682. DOI: 10.2337/dc11-1655.

[62] Cauza U, Hanusch-Enserer B, Strasser B, Ludvik B, Metz-Schimmerl S, Pacini G, Wagner O, Georg P, Prager R, Kostner K, Dunky A, Haber P. The Relative Benefits of Endurance and Strength Training on the Metabolic Factors and Muscle Function of People with type 2 Diabetes Mellitus. Archives of Physical Medicine and Rehabilitation. 2005;86(8):1527-1533. DOI: 10.1016/j.apmr.2005.01.007.

[63] Brubaker PH, Kaminsky LA, Whaley MH. Coronary Artery Disease: Essentials of Prevention and Rehabilitation Programs. Champaign, IL: Human Kinetics; 2002

[64] Shaw BS, Shaw I, Brown GA. Relationship between Resistance Training and Self-Reported Habitual Nutrient Intake. South African Journal for Research in Sport, Physical Education and Recreation, 2010;32(2): 109-116. DOI: 10.4314/sajrs.v32i2.59300.

[65] Hurley BF, Hagberg JM, Goldberg AP, Seals DR, Ehsani AA, Brennan RE, Holloszy JO. Resistive Training can Reduce Coronary Risk Factors Without Altering VO2max or Percent Body Fat. Medicine and Science in Sport and Exercise. 1988;20(2):150-154. DOI: 10.1249/00005768-198820020-00008.

[66] Keim NL, Canty DJ, Barbieri TF, Wu MM. Effect of Exercise and Dietary Restraint on Energy Intake of Reduced-Obese Women. Appetite. 1996;26(1):55-70. DOI: 10.1006/appe.1996.0005.

[67] Shaw BS, Shaw I, Brown GA. Self-Reported Dietary Intake Following Endurance, Resistance and Concurrent Endurance and Resistance Training. Journal of Sports Science and Medicine. 2008;7(2):255-259.

[68] Morgan DW, Cruise RJ, Giradin BW, Lutz-Schneider V, Morgan DH, Qi WM. HDL-C Concentrations in Weight-Trained, Endurance-Trained and Sedentary Females. Physician and SportsMedicine. 1986;14(3):166-172, 177, 180-181. DOI: 10.1080/00913847.1986.11709017.

[69] Castaneda C, Gordon PL, Uhlin KL, Levey AS, Kehayias JJ, Dwyer JT, Fielding RA, Roubenoff R, Fiatarone Singh M. Resistance Training to Counteract the Catabolism of a Low-Protein Diet in Patients with Chronic Renal Insufficiency: A Randomized, Controlled Trial. Ann Intern Med. 2001;135:965-976. DOI: 10.7326/0003-4819-135-11-200112040-00008.

[70] Menezes AR, Lavie CJ, Milani RV, O'Keefe J, Lavie TJ. Psychological Risk Factors and Cardiovascular Disease: Is it All in Your Head? Postgraduate Medicine. 2011;123(5):165-176. DOI: 10.3810/pgm.2011.09.2472.

[71] Dionigi R. Resistance Training and Older Adults' Beliefs About Psychological Benefits: The Importance of Self-Efficacy and Social Interaction. Journal of Sport & Exercise Psychology. 2007;29:723-746. DOI: 10.1123/jsep.29.6.723.

[72] Goldfield GS, Kenny GP, Alberga AS, Prud'homme D, Hadjiyannakis S, Stasia GR, Phillip P, Tulloch H, Malcolm J, Doucette S, Wells GA, Ma J, Cameron JD, Sigal RJ. Effects of Aerobic Training, Resistance Training, or Both on Psychological Health in Adolescents with Obesity: The HEARTY Randomized Controlled Trial. Journal of Consulting and Clinical Psychology. 2015;83(6):1123-1135. DOI: 10.1037/ccp0000038.

[73] Haslam DR, McCartney SN, McKelvie RS, MacDougall JD. Direct Measurements of Arterial Blood Pressure During Formal Weightlifting in Cardiac Patients. Journal of Cardiopulmonary Rehabilitation. 1988;8:213-225; DOI: 10.1097/00008483-198806000-00002.

[74] Sagiv M. Safety of Resistance Training in the Elderly. European Review of Aging and Physical Activity. 2009;6:1. DOI: 10.1007/s11556-009-0047-8.

[75] Gordon NF, Kohl HW III, Pollock ML, Vaandrager H, Gibbons LW, Blair SN. Cardiovascular Safety of Maximal Strength Testing in Healthy Adults. American Journal of Cardiology. 1995;76:851-853. DOI: 10.1016/S0002-9149(99)80245-8.

[76] Sparling PB, Cantwell JD, Dolan CM, Niederman RK. Strength Training in a Cardiac Rehabilitation Program: A Six-month Follow-up. Archives of Physical Medicine and Rehabilitation. 1990;71:148-152.

[77] Wilke NA, Sheldahl LM, Tristani FE, Hughes CV, Kalbfleisch JH. The Safety of Static-Dynamic Effort Soon after Myocardial Infarction. American Heart Journal. 1985;110:542-545. DOI: 10.1016/0002-8703(85)90072-9.

[78] American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 6th edition. Baltimore, Md: Lippincott Williams & Wilkins; 2000. ISBN: 0-683-30355-4.

[79] Fidalgo ASF, Parinatti P, Borges JP, de Paula T, Monteiro W. Institutional Guidelines for Resistance Exercise Training in Cardiovascular Disease: A Systematic Review. Sports Medicine. 2019;49(3):463-475. DOI: 10.1007/s40279-019-01059-z.

[80] Shaw BS, Turner S, Shaw I. Comparison of Muscle Endurance and Hypertrophy Resistance Training on Cardiovascular Disease Risk in Smokers. Asian Journal of Sports Medicine. 2021;12(1):1-6,e106589. DOI: 10.5812/asjsm.106589.

[81] Shaw BS, Shaw I. Resistance Training as a Countermeasure for Key Non-Communicable Diseases in Low-Resource Settings: A Review. Asian Journal of Sports Medicine. 2021;12(1):1-8,e106588. DOI: 10.5812/asjsm.106588.

[82] Kraemer WJ, Ratamess NA. Fundamentals of Resistance Training: Progression and Exercise Prescription. Medicine and Science in Sports and Exercise. 2004;36(4):674-88. DOI: 10.1249/01.mss.0000121945.36635.61.

[83] Shaw I, Boshoff VE, Coetzee S, Shaw BS. Efficacy of Home-Based Callisthenic Resistance Training on Cardiovascular Disease Risk in Overweight Compared to Normal Weight Preadolescents. Asian Journal of Sports Medicine. 2021;12(1)1-5,e106591. DOI: 10.5812/asjsm.106591.