International Journal of Strength and Conditioning

Tyler, J. R., & Thanos, P. K. (2023). Raising the Bar for Public Health: Resistance Training and Health Benefits. International Journal of Strength and Conditioning
https://doi.org/10.47206/ijsc.v3i1.195

Raising the Bar for Public Health: Resistance Training and Health Benefits

John R. Tyler[1,2] & Panayotis K. Thanos[1,3]

[1]Behavioral Neuropharmacology and Neuroimaging Laboratory on Addictions (BNNLA), Research Institute on Addictions, Department of Pharmacology and Toxicology, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, USA, [2]Department of Biomedical Sciences, University at Buffalo, USA, [3]Department of Psychology, University at Buffalo, Buffalo, USA

ABSTRACT

The major benefits of resistance training include four primary areas: cardiovascular, musculoskeletal, neuropsychological, and metabolic. Resistance exercise improves overall cardiovascular health while significantly reducing the risk of associated diseases. Cardiovascular health is specifically enhanced through the lowering of blood pressure as well as improved lipid and inflammatory profiles. Resistance training enhances musculoskeletal health through increases in bone mineral density, tendon and ligament thickness, muscle hypertrophy, and increases in balance and flexibility. Additionally, resistance training provides an effective treatment option for osteoporosis, osteopenia, sarcopenia, arthritis, and low-back pain. Neuropsychologically, resistance exercise reduces anxiety, stress, and depression, while increasing cognitive function in healthy and diseased individuals. Obesity and weight management comprise the primary metabolic focus. Resistance training effectively manages weight and body fat by increasing fat-free mass, resting metabolic rate, and caloric expenditure. Overall, resistance exercise presents an effective treatment option for disease prevention and intervention by improving health and wellness.

Keywords: brain, resistance training, health, cardiovascular, musculoskeletal, metabolic, psychological, obesity, osteoporosis, skeletal muscle

INTRODUCTION

Since the inception of structured exercise, aerobic exercise has been touted as the most beneficial and important form of exercise for general health and wellness. This claim is largely due to the plethora of clinical research surrounding aerobic exercise as opposed to other forms and modalities of training (Aguiar, Morgan, Collins, Plotnikoff, & Callister, 2014; Ismail, Keating, Baker, & Johnson, 2012; Mann, Beedie, & Jimenez, 2014; Marzolini, Oh, & Brooks, 2012; Tambalis, Panagiotakos, Kavouras, & Sidossis, 2009). With new and emerging research over the past decade, it is evident that another form of exercise is just as important; that is resistance exercise. Resistance training is defined as resisted dynamic or static muscle contraction with varying intensities (Calle & Fernandez, 2010). Recently, numerous associations including the American Heart Association (AHA) and American College of Sports Medicine (ACSM) have added resistance training to their exercise recommendations, right beside aerobic exercise in importance. For this reason, it is important to identify emerging research that has granted this heightened priority to resistance training. Therefore, the present paper serves to elucidate the various benefits and clinical applications of resistance training with a specific focus on the cardiovascular, musculoskeletal, psychological, and metabolic systems.

CARDIOVASCULAR

Given that coronary artery disease is the leading

cause of death both nationally and globally, the cardioprotective attributes of resistance training are of the utmost importance ("Exercise or Physical Activity," 2022). A recent meta-analysis found that resistance training alone confers a 17% risk reduction for cardiovascular disease and all-cause mortality (Momma, Kawakami, Honda, & Sawada, 2022). This benefit is greatly enhanced by its combination with aerobic exercise which grants a 46% and 40% lower risk of cardiovascular disease and all-cause mortality respectively (Momma et al., 2022). Much of the cardioprotective effects of muscle-strengthening exercise are attributed to metabolic, arterial, and cardiac modulation. A recent review linked important cardioprotective effects to an improved inflammatory profile of the heart through mechanisms such as reduction in lipid peroxidation levels, reactive oxygen species, and inflammatory biomarkers (Cezar, Pagan, Damatto, Lima, & Gomes, 2019). Depending on the regimen, resistance-trained individuals have been associated with a 15-45% lower risk for hypertension (M. P. Smith, 2021). A systematic review and meta-analysis from 2016 observed a 4.1 mm Hg reduction in systolic blood pressure (Lemes et al., 2016). This result is significant as a 2 mm Hg reduction in systolic blood pressure can confer around a 10% risk reduction in stroke mortality and a 7% risk reduction in mortality induced by cardiovascular disease (Lewington et al., 2002).

Another important aspect to consider for cardiovascular disease risk is lipid profile. A recent systematic review with meta-analysis found that resistance training promotes reductions in total cholesterol with a medium effect size, in triglycerides with a small effect size, in low-density lipoprotein (LDL) with a medium effect size, and in C-reactive protein levels with a large effect size (Costa et al., 2019). The same study also found that resistance training was associated with increases in high-density lipoprotein (HDL) with a medium effect size and adiponectin concentrations with a large effect size. Another meta-analysis utilized randomized controlled studies to quantify these improvements in lipid profile. Kelley and Kelley found significant reductions in total cholesterol by -5.5 mg/dl, total cholesterol to HDL ratio by -0.5, non-HDL by -8.7 ml/dl, LDL by -6.1 mg/dl, and triglycerides by -8.1 mg/dl (Kelley & Kelley, 2009). By improving lipid profile, blood pressure, and metabolic factors, resistance training is able to provide significant improvements in cardiovascular health.

Even in individuals that do suffer from cardiovascular disease, resistance training is shown in preclinical trials to improve outcomes. Resistance training prior to myocardial infarction was shown to prevent negative changes to aerobic and anaerobic capacity, prevent cardiovascular sympathetic increments, reduce sympathetic tonus to the heart and vessels, and prevent increases in left-ventricular pro-inflammatory cytokine concentrations in one preclinical trial (Barboza et al., 2016). Furthermore, preclinical research demonstrates resistance training following myocardial infarction to be a safe and effective rehabilitation tool given its significant reductions in global cardiac stress and improvements in cardiac and autonomic nervous system functioning (Grans et al., 2014).

MUSCULOSKELETAL

Perhaps the most renowned benefit of resistance training is improvement in musculoskeletal health and function. The most obvious of these benefits concerns skeletal muscle. Resistance training has been shown on numerous accounts to elicit muscle hypertrophy and increase strength, flexibility, and balance thus proving a powerful tool in the treatment of sarcopenia (De Spiegeleer, Petrovic, Boeckxstaens, & Van Den Noortgate, 2016). A recent review paper identified the atrophy of myosin heavy chain (MHC) II fibres as the primary source of age-related decrements in skeletal muscle function (Grosicki, Zepeda, & Sundberg, 2022). This finding is significant as clear evidence now supports that muscle preservation with aging is almost exclusively a fast-twitch fiber problem. Therefore, resistance training is supported as a highly effective solution as it is the most effective exercise modality for eliciting MHC type II fibres hypertrophy and thus attenuating age-related strength and power decline (Grosicki et al., 2022). Through muscular adaptation, resistance training also markedly reduces the overall risk and severity of musculoskeletal injury due to its positive effects on bone mineral density, connective tissue, and muscle mass (Hoffman, 2017). These improvements in bone mineral density then transfer over to its efficacy in the treatment of osteoporosis and osteopenia. A recent meta-analysis analyzed the effect of high-load resistance training on bone mineral density in osteoporotic and osteopenic patients. Kitsuda et al. observed significant increases in bone mineral density of the lumbar spine, femoral neck, and total hip (Kitsuda, Wada, Noma, Osaki, & Hagino, 2021).

The unprecedented efficacy of resistance training

in the treatment of osteoporosis was specifically elucidated by the Lifting Intervention For Training Muscle and Osteoporosis Rehabilitation (LIFTMOR) trial. This study implemented a high-intensity progressive resistance training program for postmenopausal women with low to very low bone mass, 28% of the women having sustained osteoporotic fractures within the last 10 years (Watson, Weeks, Weis, Horan, & Beck, 2015). Not only was this heavy-lifting program safe and effective for these high-risk patients, but it also precipitated promising results. A 2.9% and 0.3% increase in bone mineral density were observed in the lumbar spine and femoral neck of the treatment group respectively (Watson et al., 2015). Although these may seem like minuscule improvements, the 0.3% increase in bone mineral density observed at the femoral neck resulted in a 13.6% increase in cortical thickness of the femoral neck (Watson et al., 2015). For comparison, bisphosphonate treatment, which is the standard of care for osteoporosis, was found to increase bone mineral density by 3.5% at the lumbar spine and 1.9% at the femoral neck after two years of treatment while the LIFTMOR study utilized just eight months of resistance training to produce comparable results (Hosking et al., 1998).

When considering the musculoskeletal system, it is also important to consider everything in between the bones and muscles. Resistance training is particularly effective in improving connective tissue health, specifically by increasing tendon and ligament thickness (Grzelak, Podgorski, Stefanczyk, Krochmalski, & Domzalski, 2012; Mersmann, Bohm, & Arampatzis, 2017). In professional weightlifters, mean cross-sectional area of the patellar ligament was 37.1% greater than in the control group (Grzelak et al., 2012). These improvements in joint health are particularly evident in the treatment of pathological conditions. In patients with rheumatoid arthritis, resistance training is considered “an important cornerstone of the nonpharmacological treatment” (Häkkinen, 2004). Controlled clinical research has demonstrated the efficacy of resistance training in reducing disease activity and associated pain in patients with rheumatoid arthritis (Strasser et al., 2011). As for osteoarthritis, resistance training is also effective in improving symptomatology and physical performance (Lange, Vanwanseele, & Fiatarone singh, 2008). One of the most common sources of musculoskeletal pain, and even pain in general, is low back pain. U.S. Nationals Surveys found that low back pain is the most common type of pain reported by patients in the U.S. within a three-month timeframe with a 26.4% prevalence (Deyo, Mirza, & Martin, 2006). After just eight weeks of resistance training, significant improvements in low back-associated pain, disability, and quality of life were conferred by treatment (Jackson, Shepherd, & Kell, 2011). Depending on the regimen, individuals can expect an overall reduction in the intensity of back pain ranging from 10% to 50% following resistance training (Rainville et al., 2004). Together, the improvements in the health of muscles, bones, and connective tissues comprise the various musculoskeletal benefits of resistance exercise.

PSYCHOLOGICAL/NEUROLOGICAL

Although resistance training presents numerous physical benefits, less obvious, yet equally important, are the psychological and neurological benefits. Past research has shown significant improvements in quality of life, anxiety, body image, and stress ratings for strength-trained individuals (Rica et al., 2018; Westcott, 2012). As for cognitive benefits, a recent systematic review and meta-analysis showed that resistance training significantly improved overall cognitive function with a medium effect in healthy and cognitively impaired adults (Coelho-Junior et al., 2022). Resistance training was associated with a significant positive effect on cognitive scores, measures of cognitive impairment, and executive functions (Landrigan, Bell, Crowe, Clay, & Mirman, 2020). Resistance training is also an effective treatment option for several neurological and psychological disorders. Progressive resistance training was shown to improve cognitive symptoms of dementia with marked improvement of cognitive function in patients with mild cognitive impairment (Fiatarone Singh et al., 2014). Resistance training also offers an effective treatment modality for the reduction of PTSD symptomology (Rosenbaum, Sherrington, & Tiedemann, 2015). With a prevalence of 8.4% in the U.S., major depressive disorder represents one of the most common psychological disorders among Americans (Schulenberg et al., 2021). Substantial evidence supports the efficacy of resistance training as a valid intervention for reducing adult depressive symptoms (O’Connor, Herring, & Caravalho, 2010). After just 10 weeks of a resistance training program, clinical depression was successfully treated in more than 80% of the elderly group (Singh, Clements, & Fiatarone, 1997). Paired with aerobic activity, 10 weeks of resistance training was shown to confer significant improvements in physical self-concept, fatigue, revitalization, tension, tranquility, positive engagement, and total mood disturbance (Westcott, 2012). The aforementioned

benefits provide evidence for resistance exercise to be a powerful tool and treatment option for improving psychological health.

Recent research has highlighted the efficacy of resistance training as an adjunct treatment for addiction and drug abuse. Resistance training has been shown to significantly increase dopamine and serotonin levels in addicted subjects, helping to restore deficits following drug abuse (Akbarpour, Fathollahi Shoorabeh, Moradpourian, & Mozaffari, 2020; Arazi, Dadvand, & Fard, 2017; Arazi, Damirchi, & Poulab, 2016). Preclinical research demonstrated that resistance exercise significantly decreases the positive reinforcing effects of heroin and cocaine through modulation of mu opioid and dopamine receptors (M. A. Smith et al., 2018; Strickland et al., 2016). Although research on resistance training for treating addiction is still scarce and young, the data that does exist is promising.

METABOLISM

The final major area of efficacy and clinical application for resistance training lies in weight management and the treatment of obesity. With a prevalence of 42.4% in 2017 - 2018 and an estimated 3% increase from 2019 to 2020, obesity is a major public health crisis and was recently labeled a national epidemic in the United States (Cdc, 2022; Tiwari & Balasundaram, 2022). As opposed to other exercise modalities such as aerobic exercise, resistance exercise confers greater efficacy for weight management due to its significant impact on metabolism. By increasing fat-free mass, the individual burns more calories in and outside the gym due to increases in resting metabolic rate. This finding was confirmed by numerous studies demonstrating significant increases in fat-free mass and resting metabolic rate following a resistance training program (Broeder, Burrhus, Svanevik, & Wilmore, 1992; Campbell, Crim, Young, & Evans, 1994; Greer, Sirithienthad, Moffatt, Marcello, & Panton, 2015; Hunter, Wetzstein, Fields, Brown, & Bamman, 2000; Lemmer et al., 2001; Pratley et al., 1994; Van Etten, Westerterp, Verstappen, Boon, & Saris, 1997). On average, a 1.4 kg gain of lean weight and a 1.8 kg loss of fat were conferred by the aforementioned resistance training studies. This increase in fat-free mass proves significant as energy expenditure is directly linked to fat-free mass and body weight (Health, 1989). The estimation of the resting metabolic rate of skeletal muscle is 12.6 kcal/kg per day, compared to that of adipose tissue which is 4.4 kcal/kg per day (Wang et al., 2010). The old adage that muscle burns more calories than fat remains true; however, it is important to recognize that this comparison only exists relative to adipose tissue as major organs such as the heart and kidneys have much higher resting metabolic rates relative to their weight. A six week moderate intensity resistance training program reported a 246.76Kcal*day-1 increase in basal metabolic rate which accurately reflects average results across moderate resistance training protocols (Stavres, Zeigler, & Bayles, 2018). Resistance training also elicits extra caloric expenditure post-workout for recovery processes. This phenomenon is demonstrated through analysis of post-exercise oxygen consumption (EPOC) which effectively reflects caloric expenditure. A controlled clinical trial found that resistance training, as opposed to steady-state aerobic exercise, induced significantly greater EPOC (Greer et al., 2015). These processes directly correlate as protein synthesis and degradation account for approximately 20% of resting metabolic rate (Rasmussen & Phillips, 2003). Just 20 minutes of circuit resistance training can utilize approximately 200 kcal while requiring an additional 25% of total energy expenditure for the first hour succeeding the workout for recovery processes (Haltom et al., 1999). Even at 72 hours following resistance training, resting energy expenditure was found to be elevated by 5%, which equated to around 100 calories per day, compared to baseline (Heden, Lox, Rose, Reid, & Kirk, 2011). Overall, resistance training is highly effective for weight and metabolism management. Resistance training is especially effective in type II diabetes prevention and intervention. Efficacy is conferred through improvement of glycemic control, body fat percentage, and blood lipids (Qadir, Sculthorpe, Todd, & Brown, 2021). An extensive review conducted by Strasser and Schobersberger concluded that resistance training is a recommended and efficacious treatment option for obesity and metabolic disorders (Strasser & Schobersberger, 2011).

CONCLUSION

While we elucidate the major positive side effects associated with resistance training, there are still numerous other benefits not mentioned here. The cardiovascular, musculoskeletal, neuropsychological, and metabolic systems represent four major areas that resistance exercise is known to significantly benefit. These effects are directly and concisely reflected by the significant improvement in all-cause mortality and quality of

life. Not only is resistance training preventative medicine through its reduction in disease risk and enhancement of health and wellness, but it is also an effective intervention through its alleviation of disease signs and symptoms. Overall, the already extensive benefit of resistance exercise will only continue to develop as emerging research elucidates new applications.

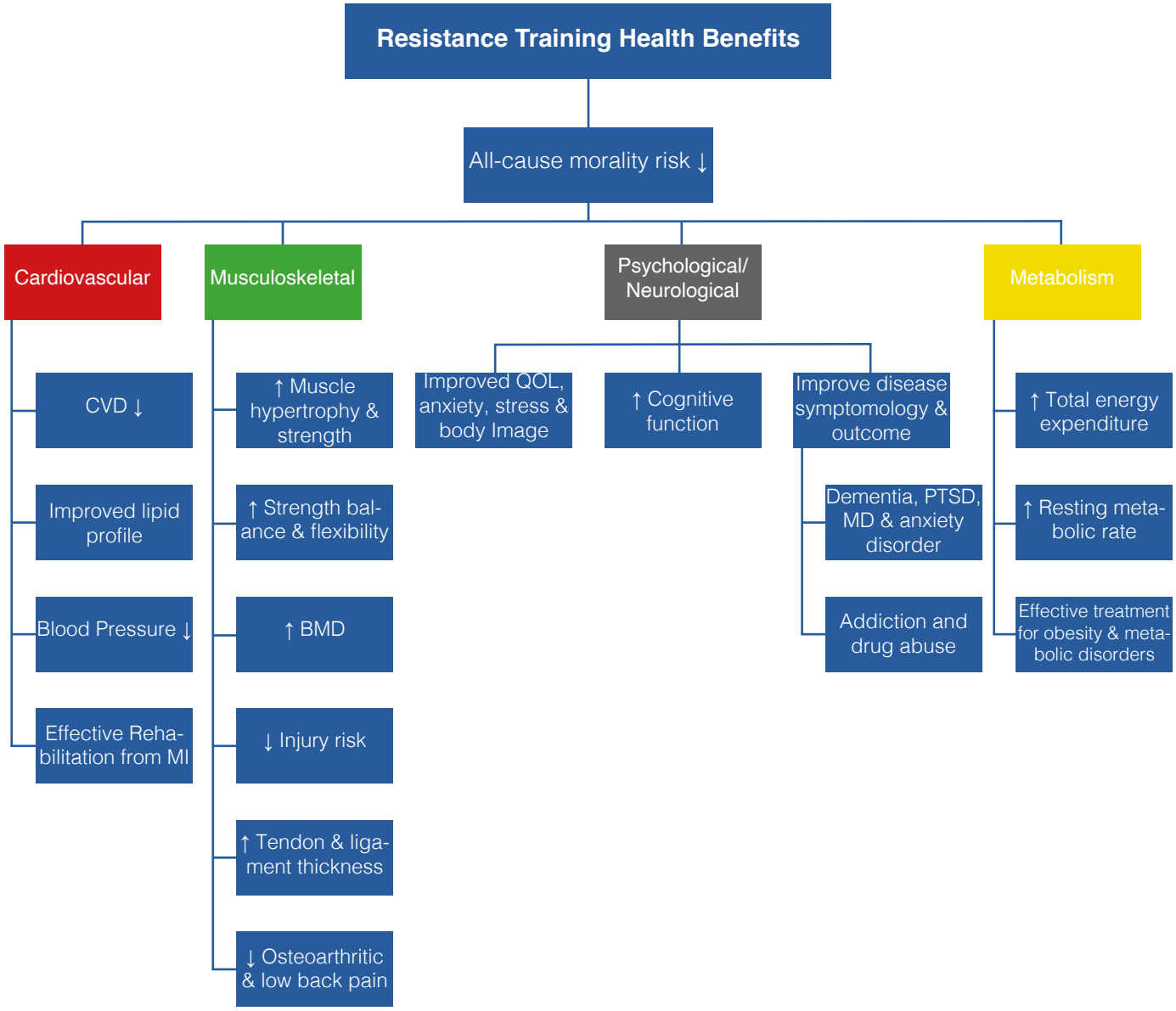

Figure 1.

Notes: Cardiovascular disease (CVD), Myocardial infarction (MI), Bone mineral density (BMD), Quality of life (Qol), Major depressive disorder (MDD)

REFERENCES

1. Aguiar, E. J., Morgan, P. J., Collins, C. E., Plotnikoff, R. C., & Callister, R. (2014). Efficacy of interventions that include diet, aerobic and resistance training components for type 2 diabetes prevention: a systematic review with meta-analysis. International Journal of Behavioral Nutrition and Physical Activity, 11(1), 1-10.
2. Akbarpour, M., Fathollahi Shoorabeh, F., Moradpourian, M., & Mozaffari, H. (2020). The Effect of Resistance Training on Some Neurotransmitters and Men's Pulmonary Function After Leaving Addiction. Int Electron J Med, 9(1), 26-30. doi:10.34172/iejm.2020.05
3. Arazi, H., Dadvand, S. S., & Fard, M. T. (2017). Neurotransmitters and cardiovascular responses to aerobic and resistance exercise in men addicted to methamphetamine. Baltic Journal of Sport and Health Sciences, 3(106).
4. Arazi, H., Damirchi, A., & Poulab, E. (2016). The effect of seven weeks of combined (aerobic-resistance) training on blood levels of serotonin and dopamine and physical fitness factors of addicted men to methamphetamine during rehabilitation.
5. Barboza, C. A., Souza, G. I. H., Oliveira, J. C. M. F., Silva, L. M., Mostarda, C. T., Dourado, P. M. M., . . . Rodrigues, B. (2016). Cardioprotective Properties of Aerobic and Resistance Training Against Myocardial Infarction. International Journal of Sports Medicine, 37(6), 421-430. doi:10.1055/s-0035-1565136
6. Broeder, C. E., Burrhus, K. A., Svanevik, L. S., & Wilmore, J. H. (1992). The effects of either high-intensity resistance or endurance training on resting metabolic rate. The American Journal of Clinical Nutrition, 55(4), 802-810. doi:10.1093/ajcn/55.4.802
7. Calle, M. C., & Fernandez, M. L. (2010). Effects of resistance training on the inflammatory response. nrp, 4(4), 259-269. doi:10.4162/nrp.2010.4.4.259
8. Campbell, W. W., Crim, M. C., Young, V. R., & Evans, W. J. (1994). Increased energy requirements and changes in body composition with resistance training in older adults. The American Journal of Clinical Nutrition, 60(2), 167-175. doi:10.1093/ajcn/60.2.167
9. Cdc. (2022). Obesity is a Common, Serious, and Costly Disease. Centers for Disease Control and Prevention. Retrieved from https://www.cdc.gov/obesity/data/adult.html
10. files/43/adult.html
11. Cezar, M. D. M., Pagan, L. U., Damatto, R. L., Lima, A., & Gomes, M. J. (2019). Cardioprotective Effects of Resistance Training on Obesity. Arquivos Brasileiros de Cardiologia, 112(5), 553-554. doi:10.5935/abc.20190085
12. Coelho-Junior, H., Marzetti, E., Calvani, R., Picca, A., Arai, H., & Uchida, M. (2022). Resistance training improves cognitive function in older adults with different cognitive status: a systematic review and Meta-analysis. Aging & Mental Health, 26(2), 213-224. doi:10.1080/13607863.2020.1857691
13. Costa, R. R., Buttelli, A. C. K., Vieira, A. F., Coconcelli, L., Magalhães, R. d. L., Delevatti, R. S., & Kruel, L. F. M. (2019). Effect of Strength Training on Lipid and Inflammatory Outcomes: Systematic Review With Meta-Analysis and Meta-Regression. Journal of Physical Activity and Health, 16(6), 477-491. doi:10.1123/jpah.2018-0317
14. De Spiegeleer, A., Petrovic, M., Boeckxstaens, P., & Van Den Noortgate, N. (2016). Treating sarcopenia in clinical practice: where are we now? Acta Clinica Belgica, 71(4), 197-205. doi:10.1080/17843286.2016.1168064
15. Deyo, R. A., Mirza, S. K., & Martin, B. I. (2006). Back pain prevalence and visit rates: estimates from U.S. national surveys, 2002. Spine, 31(23), 2724-2727. doi:10.1097/01.brs.0000244618.06877.cd
16. Exercise or Physical Activity. (2022). Centers for Disease Control and Prevention (CDC). Retrieved from https://www.cdc.gov/nchs/fastats/exercise.htm
17. files/8/exercise.html
18. Fiatarone Singh, M. A., Gates, N., Saigal, N., Wilson, G. C., Meiklejohn, J., Brodaty, H., . . . Valenzuela, M. (2014). The Study of Mental and Resistance Training (SMART) study—resistance training and/or cognitive training in mild cognitive impairment: a randomized, double-blind, double-sham controlled trial. Journal of the American Medical Directors Association, 15(12), 873-880. doi:10.1016/j.jamda.2014.09.010
19. Grans, C. F., Feriani, D. J., Abssamra, M. E. V., Rocha, L. Y., Carrozzi, N. M., Mostarda, C., . . . Rodrigues, B. (2014). Resistance Training After Myocardial Infarction in Rats: Its Role on Cardiac and Autonomic Function. Arquivos Brasileiros de Cardiologia, 103, 60-68. doi:10.5935/abc.20140093
20. Greer, B. K., Sirithienthad, P., Moffatt, R. J., Marcello, R. T., & Panton, L. B. (2015). EPOC Comparison Between Isocaloric Bouts of Steady-State Aerobic, Intermittent Aerobic, and Resistance Training. Research Quarterly for Exercise and Sport, 86(2), 190-195. doi:10.1080/02701367.2014.999190
21. Grosicki, G. J., Zepeda, C. S., & Sundberg, C. W. (2022). Single muscle fibre contractile function with ageing. The Journal of Physiology. doi:10.1113/JP282298
22. Grzelak, P., Podgorski, M., Stefanczyk, L., Krochmalski, M., & Domzalski, M. (2012). Hypertrophied cruciate ligament in high performance weightlifters observed in magnetic resonance imaging. Int Orthop, 36(8), 1715-1719. doi:10.1007/s00264-012-1528-3
23. Häkkinen, A. (2004). Effectiveness and safety of strength training in rheumatoid arthritis. Current Opinion in Rheumatology, 16(2). Retrieved from https://journals.lww.com/co-rheumatology/Fulltext/2004/03000/Effectiveness_and_safety_of_strength_training_in.11.aspx
24. Haltom, R. W., Kraemer, R. R., Sloan, R. A., Hebert, E. P., Frank, K., & Tryniecki, J. L. (1999). Circuit weight training and its effects on excess postexercise oxygen consumption. Medicine and Science in Sports and Exercise, 31(11), 1613-1618. doi:10.1097/00005768-

199911000-00018
25. Health, N. R. C. U. C. o. D. a. (1989). Diet and Health: Implications for Reducing Chronic Disease Risk. In National Research Council (US) Committee on Diet and Health. Diet and Health: Implications for Reducing Chronic Disease Risk: Washington (DC): National Academies Press (US).
26. Heden, T., Lox, C., Rose, P., Reid, S., & Kirk, E. P. (2011). One-set resistance training elevates energy expenditure for 72 h similar to three sets. European Journal of Applied Physiology, 111(3), 477-484. doi:10.1007/s00421-010-1666-5
27. Hoffman, J. (2017). Resistance Training and Injury Prevention. In: American College of Sports Medicine.
28. Hosking, D., Chilvers, C. E., Christiansen, C., Ravn, P., Wasnich, R., Ross, P., . . . Yates, A. J. (1998). Prevention of bone loss with alendronate in postmenopausal women under 60 years of age. Early Postmenopausal Intervention Cohort Study Group. The New England Journal of Medicine, 338(8), 485-492. doi:10.1056/NEJM199802193380801
29. Hunter, G. R., Wetzstein, C. J., Fields, D. A., Brown, A., & Bamman, M. M. (2000). Resistance training increases total energy expenditure and free-living physical activity in older adults. Journal of Applied Physiology (Bethesda, Md.: 1985), 89(3), 977-984. doi:10.1152/jappl.2000.89.3.977
30. Ismail, I., Keating, S. E., Baker, M. K., & Johnson, N. A. (2012). A systematic review and meta-analysis of the effect of aerobic vs. resistance exercise training on visceral fat. Obesity reviews, 13(1), 68-91.
31. Jackson, J. K., Shepherd, T. R., & Kell, R. T. (2011). The Influence of Periodized Resistance Training on Recreationally Active Males with Chronic Nonspecific Low Back Pain. The Journal of Strength & Conditioning Research, 25(1). Retrieved from https://journals.lww.com/nsca-jscr/Fulltext/2011/01000/The_Influence_of_Periodized_Resistance_Training_on.35.aspx
32. Kelley, G. A., & Kelley, K. S. (2009). Impact of progressive resistance training on lipids and lipoproteins in adults: A meta-analysis of randomized controlled trials. Preventive Medicine, 48(1), 9-19. doi:10.1016/j.ypmed.2008.10.010
33. Kitsuda, Y., Wada, T., Noma, H., Osaki, M., & Hagino, H. (2021). Impact of high-load resistance training on bone mineral density in osteoporosis and osteopenia: a meta-analysis. Journal of Bone and Mineral Metabolism, 39(5), 787-803. doi:10.1007/s00774-021-01218-1
34. Landrigan, J.-F., Bell, T., Crowe, M., Clay, O. J., & Mirman, D. (2020). Lifting cognition: a meta-analysis of effects of resistance exercise on cognition. Psychological Research, 84(5), 1167-1183. doi:10.1007/s00426-019-01145-x
35. Lange, A. K., Vanwanseele, B., & Fiatarone singh, M. A. (2008). Strength training for treatment of osteoarthritis of the knee: A systematic review. Arthritis Care & Research, 59(10), 1488-1494. doi:10.1002/art.24118
36. Lemes, Í. R., Ferreira, P. H., Linares, S. N., Machado, A. F., Pastre, C. M., & Netto, J. (2016). Resistance training reduces systolic blood pressure in metabolic syndrome: a systematic review and meta-analysis of randomised controlled trials. British Journal of Sports Medicine, 50(23), 1438-1442. doi:10.1136/bjsports-2015-094715
37. Lemmer, J. T., Ivey, F. M., Ryan, A. S., Martel, G. F., Hurlbut, D. E., Metter, J. E., . . . Hurley, B. F. (2001). Effect of strength training on resting metabolic rate and physical activity: age and gender comparisons. Med Sci Sports Exerc, 33(4), 532-541. doi:10.1097/00005768-200104000-00005
38. Lewington, S., Clarke, R., Qizilbash, N., Peto, R., Collins, R., & Prospective Studies, C. (2002). Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet (London, England), 360(9349), 1903-1913. doi:10.1016/s0140-6736(02)11911-8
39. Mann, S., Beedie, C., & Jimenez, A. (2014). Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: review, synthesis and recommendations. Sports Medicine, 44(2), 211-221.
40. Marzolini, S., Oh, P. I., & Brooks, D. (2012). Effect of combined aerobic and resistance training versus aerobic training alone in individuals with coronary artery disease: a meta-analysis. European journal of preventive cardiology, 19(1), 81-94.
41. Mersmann, F., Bohm, S., & Arampatzis, A. (2017). Imbalances in the Development of Muscle and Tendon as Risk Factor for Tendinopathies in Youth Athletes: A Review of Current Evidence and Concepts of Prevention. Frontiers in Physiology, 8.
42. Momma, H., Kawakami, R., Honda, T., & Sawada, S. S. (2022). Muscle-strengthening activities are associated with lower risk and mortality in major non-communicable diseases: a systematic review and meta-analysis of cohort studies. British Journal of Sports Medicine, 56(13), 755. doi:10.1136/bjsports-2021-105061
43. O'Connor, P. J., Herring, M. P., & Caravalho, A. (2010). Mental health benefits of strength training in adults. American Journal of Lifestyle Medicine, 4(5), 377-396.
44. Pratley, R., Nicklas, B., Rubin, M., Miller, J., Smith, A., Smith, M., . . . Goldberg, A. (1994). Strength training increases resting metabolic rate and norepinephrine levels in healthy 50- to 65-yr-old men. Journal of Applied Physiology (Bethesda, Md.: 1985), 76(1), 133-137. doi:10.1152/jappl.1994.76.1.133
45. Qadir, R., Sculthorpe, N. F., Todd, T., & Brown, E. C. (2021). Effectiveness of Resistance Training and Associated Program Characteristics in Patients at Risk for Type 2 Diabetes: a Systematic Review and Meta-analysis. Sports Medicine - Open, 7(1), 38. doi:10.1186/s40798-021-00321-x
46. Rainville, J., Hartigan, C., Martinez, E., Limke, J., Jouve, C., & Finno, M. (2004). Exercise as a treatment for chronic low back pain. The Spine Journal, 4(1), 106-115. doi:10.1016/S1529-9430(03)00174-8

47. Rasmussen, B. B., & Phillips, S. M. (2003). Contractile and nutritional regulation of human muscle growth. Exercise and Sport Sciences Reviews, 31(3), 127-131. doi:10.1097/00003677-200307000-00005
48. Rica, R. L., Gama, E. F., Machado, A. F., Alonso, A. C., Evangelista, A. L., Figueira-Junior, A., . . . Bocalini, D. S. (2018). Does resistance training improve body image satisfaction among the elderly? A cross-sectional study. Clinics, 73, e290. doi:10.6061/clinics/2018/e290
49. Rosenbaum, S., Sherrington, C., & Tiedemann, A. (2015). Exercise augmentation compared with usual care for post-traumatic stress disorder: a randomized controlled trial. Acta Psychiatrica Scandinavica, 131(5), 350-359. doi:10.1111/acps.12371
50. Schulenberg, J. E., Patrick, M. E., Johnston, L. D., O'Malley, P. M., Bachman, J. G., & Miech, R. A. (2021). Monitoring the Future National Survey Results on Drug Use, 1975-2020. Volume II, College Students & Adults Ages 19-60. Institute for Social Research.
51. Singh, N. A., Clements, K. M., & Fiatarone, M. A. (1997). A randomized controlled trial of progressive resistance training in depressed elders. The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 52(1), M27-35. doi:10.1093/gerona/52a.1.m27
52. Smith, M. A., Fronk, G. E., Abel, J. M., Lacy, R. T., Bills, S. E., & Lynch, W. J. (2018). Resistance exercise decreases heroin self-administration and alters gene expression in the nucleus accumbens of heroin-exposed rats. Psychopharmacology, 235(4), 1245-1255. doi:10.1007/s00213-018-4840-9
53. Smith, M. P. (2021). Cardioprotective effects of resistance training add to those of total activity in Americans. Annals of Epidemiology, 62, 13-18. doi:10.1016/j.annepidem.2021.05.007
54. Stavres, J., Zeigler, M., & Bayles, M. (2018). Six weeks of moderate functional resistance training increases basal metabolic rate in apparently healthy adult women. International Journal of Exercise Science, 11, 32-41.
55. Strasser, B., Leeb, G., Strehblow, C., Schobersberger, W., Haber, P., & Cauza, E. (2011). The effects of strength and endurance training in patients with rheumatoid arthritis. Clinical Rheumatology, 30(5), 623-632. doi:10.1007/s10067-010-1584-2
56. Strasser, B., & Schobersberger, W. (2011). Evidence for Resistance Training as a Treatment Therapy in Obesity. Journal of Obesity, 2011, 482564. doi:10.1155/2011/482564
57. Strickland, J. C., Abel, J. M., Lacy, R. T., Beckmann, J. S., Witte, M. A., Lynch, W. J., & Smith, M. A. (2016). The effects of resistance exercise on cocaine self-administration, muscle hypertrophy, and BDNF expression in the nucleus accumbens. Drug and alcohol dependence, 163, 186-194.
58. Tambalis, K., Panagiotakos, D. B., Kavouras, S. A., & Sidossis, L. S. (2009). Responses of blood lipids to aerobic, resistance, and combined aerobic with resistance exercise training: a systematic review of current evidence. Angiology, 60(5), 614-632.
59. Tiwari, A., & Balasundaram, P. (2022). Public Health Considerations Regarding Obesity. In StatPearls. Treasure Island (FL): StatPearls Publishing.
60. Van Etten, L. M., Westerterp, K. R., Verstappen, F. T., Boon, B. J., & Saris, W. H. (1997). Effect of an 18-wk weight-training program on energy expenditure and physical activity. Journal of Applied Physiology (Bethesda, Md.: 1985), 82(1), 298-304. doi:10.1152/jappl.1997.82.1.298
61. Wang, Z., Ying, Z., Bosy-Westphal, A., Zhang, J., Schautz, B., Later, W., . . . Müller, M. J. (2010). Specific metabolic rates of major organs and tissues across adulthood: evaluation by mechanistic model of resting energy expenditure1234. The American Journal of Clinical Nutrition, 92(6), 1369-1377. doi:10.3945/ajcn.2010.29885
62. Watson, S. L., Weeks, B. K., Weis, L. J., Horan, S. A., & Beck, B. R. (2015). Heavy resistance training is safe and improves bone, function, and stature in postmenopausal women with low to very low bone mass: novel early findings from the LIFTMOR trial. Osteoporosis international: a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA, 26(12), 2889-2894. doi:10.1007/s00198-015-3263-2
63. Westcott, W. L. (2012). Resistance Training is Medicine: Effects of Strength Training on Health. Current Sports Medicine Reports, 11(4). Retrieved from https://journals.lww.com/acsm-csmr/Fulltext/2012/07000/Resistance_Training_is_Medicine__Effects_of.13.aspx
64. Westcott, W. L. (2012). Resistance Training is Medicine: Effects of Strength Training on Health. Current Sports Medicine Reports, 11(4). Retrieved from https://journals.lww.com/acsm-csmr/Fulltext/2012/07000/Resistance_Training_is_Medicine__Effects_of.13.aspx