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# Exercise and Chronic Diseases: A Scoping Review

Moh. Ali Imron[1,2], I Putu Gede Adiatmika[2], I Made Jawi[2]

[1] Department of Physiotherapy; Aisyiyah University Yogyakarta; Indonesia
[2] Department of Medical Science; Udayana University; Indonesia

**Corresponding Author:**
Moh. Ali Imron: Department of Physiotherapy, Áisyiyah University of Yogyakarta, Indonesia
Email: aliimron@unisayogya.ac.id

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**ABSTRACT**

**Background:** Regular exercise has been postulated as beneficial to prevent, treat, and manage a chronic disease that nowadays is caused by a sedentary life. However, its prescription and mechanism of how exercise positively affects health conditions is requiring further research. **Objective:** To investigate the types of regular exercise and exercise prescription and mechanisms in preventing or treating a chronic disease. **Methods:** This study reviewed articles from ProQuest, Science Direct, Wiley, and PubMed using the terms 'chronic disease', 'exercise', 'physical activity', and 'cytokine'. **Results:** Forty-six articles were reviewed in this study which originated from different regions spanning Asia, Europe, America, and Africa. The articles were categorized based on sample characteristics, which were; elderly, healthy adults, athletes, mice, and others. Each article describes an aerobic or anaerobic exercise performed under various interventions ranging from low, moderate, to high and comprehensively explains its effect on human biology, including on the body system, tissue adaptation, muscle hypertrophy, and neuroplasticity, by examining its effect on proteins, hormones, enzymes, microRNAs, as well as functional metrics pertaining to physical capacity enhancement. **Conclusion:** This review concludes that exercise will elicit effects on the immune and metabolic systems of people with chronic disease.

**Keywords:** *chronic disease; exercise; immune system, metabolic system*

## BACKGROUND

A sedentary lifestyle is becoming increasingly widespread across generations. Advances in communication technology have made life easier. Recently, a screen-based lifestyle has emerged, with many people spending 24 hours a day in front of a screen and lacking physical activity. The health risks of this lifestyle have been demonstrated by numerous studies. Lack of activity can put a person at risk of developing chronic diseases later in life. Obesity, type 2 diabetes, high blood pressure, and cardiovascular disease are consistently linked to a sedentary lifestyle[1,2].

Prevention and treatment using pharmacological approaches are essential, in addition to dietary regulation. Exercise is an important non-pharmacological measure in efforts to maintain a healthy body that has long roots in human history. History has recorded that an Indian physician named Sushruta 600 BCE has placed exercise as a crucial element in maintaining physiological body balance, thus freeing from pain. History also records that Hippocrates 460 BCE continued the importance of exercise in the very popular statement that the body not only needs food but also needs exercise[3]. Long before that, Herodicus 500 BCE, considered Hippocrates' teacher, first explained the benefits of exercise therapy and was named the "father of exercise medicine"[4].

"Exercise is medicine" was reiterated by the American College of Sports Medicine (ACSM) in 2007 in a global initiative, encouraging physicians and health professionals to use exercise prescriptions to prevent and treat illnesses, especially chronic ones. As of 2014, the PubMed database had recorded 56,691 citations related to exercise is medicine.

Further research is needed to understand how exercise affects health and when exercise should be administered to hospitalized patients, such as those with chronic renal disease[14]. Furthermore, in daily practice, hospital physicians have not sufficiently focused on and incorporated exercise into their prescriptions. Many difficulties remain regarding how exercise can be performed in critically ill individuals, coupled with difficulties in determining dosage[21]. This may be due to a lack of dissemination of information related to the evidence base for exercise.

This article discusses in vivo experimental research on the types of regular exercise and their mechanisms in the body as a means of preventing and managing chronic disease. It is hoped that this review will enrich the reference list for exercise utilization and gradually eliminate doubts about implementing regular exercise in the healthcare world.

## RESEARCH METHODS

All articles used in this scoping review were accessed from four databases: ProQuest, Science Direct, Wiley, and

PubMed. Articles were searched using keywords defined by PICO, namely, chronic disease, exercise, physical activity, and cytokine. Database access was performed using the aforementioned keywords, and the number of articles appearing was selected based on the title of the review.

The reviewed articles met the inclusion criteria, namely full-text articles that were international articles, both in the form of randomized controlled trials and in vivo articles published between 2013 and 2023. Exclusion criteria included in vitro RCT articles, published before 2013, and not in English. The obtained articles were screened for duplication, then abstract screening to filter articles that were in accordance with the predetermined PICO and continued with full-text screening to include the articles into the inclusion criteria (Figure 1). Articles that met the inclusion criteria were then categorized based on the type of population where the exercise was given.

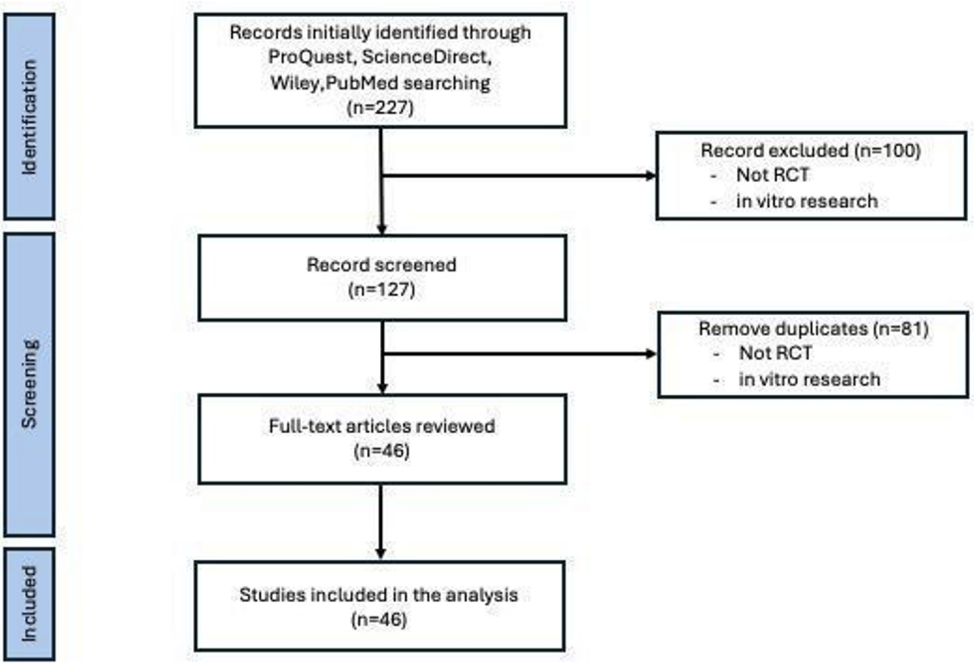


**Figure 1.** Flow chart

## RESULTS

Forty-six articles were selected for review from a pool of 227 (Table 1). The articles originated from Asia, Europe, America, and Africa and were then categorized based on sample type: healthy individuals (including the elderly, athletes, young people, and mice), and patients (including patients receiving exercise interventions of varying types and dosages).

*Exercise*Regular exercise is a highly recommended non-pharmacological measure for preventing, treating, and managing chronic diseases[1,5]. The benefits of regular exercise are not limited to healthy people[6] but also to people who have experienced health problems in almost all body systems, including musculoskeletal[5,6,7,8,9], respiratory[5], heart and blood vessels[10], liver[11], brain[9,12,13], kidney[14], aging and cognitive disorders[13,14,15], and even for pregnant women[13]. Regular exercise also has a positive impact on cancer prevention[16,17,18,19] and improving the quality of life of cancer patients[20]. In regenerative therapy, regular exercise supports the integration of stem cells with tissue[21,22,23].

## DISCUSSION

This review found that exercise, whether for promotion, prevention, curation, or rehabilitation, can address various health issues, particularly chronic diseases, in populations of varying ages across countries. Furthermore, both aerobic and anaerobic exercise, at low, moderate, and high intensities, and for exercise durations ranging from weeks to months, can positively impact the entire body's systems, tissue adaptation, muscle hypertrophy, and neuroplasticity, by examining its effects on proteins, hormones, enzymes, micro RNA, and functional measures of physical capacity.

*Exercise*is a form of physical activity carried out with the aim of obtaining health benefits with structured and continuous planning[1]. However, using exercise as an intervention for various health conditions requires a precise understanding of the body's response to exercise, and how exercise is able to prevent and/or improve conditions[1,7].

Muscle contraction during exercise is a mechanical stimulus to which the body responds with cellular and molecular activity, the molecular mechanisms of which can be identified through biomarkers[24]. In general, exercise causes changes in metabolic and immunological processes[1,18,21]. Given the complexity of exercise's effects on health, this review presents two main topics: exercise and immunology and exercise and metabolism.

### Exercise and Immunobiology

*Remodeling process*or what is also called immunosenescence is a process that involves changes in the

leukocyte population and dysregulation of most immune functions in the body[25]. Skeletal muscle is an endocrine organ that secretes various biologically active peptides and proteins called myokines after receiving stimulation in the form of muscle contraction. The expression and secretion of myokines or other cytokine groups will increase immediately after exercise[1,6]. In the immunological aspect, exercise not only increases natural immunity but also increases acquired immunity along with modulating the inflammatory environment and immune response[5]. Some of the cytokines in question are IL-6, IL-1β, IL-10, TNF-α, LIF and others[1,5,26].

*Chronic disease*is associated with low-grade systemic inflammation, characterized by increased proinflammatory cytokines. Myokines circulate through the bloodstream and, through the endocrine system, benefit organs outside the muscle, such as the liver, lungs, and blood vessels[1,26]. Furthermore, the circulation of myokines, including IL-6, outside the muscle plays a role in regulating glucose and fat metabolism. Cytokine expression after exercise ultimately has an anti-inflammatory effect.

*Inflamasome*is a protein complex that plays a role in body defense and inflammation. Activation and expression of the inflammasome, one of which is NLRP3, will activate Reactive Oxygen Species (ROS). ROS will trigger NLRP3-mediated inflammation in cases of Nonalcoholic Steatohepatitis (NASH). Inhibition of NLRP3 inflamsome activation reduces hepatic inflammation. The role of exercise in controlling NLRP3 inflammasome expression induced inflammation mediated by adropin through ROS inhibition[11].

*Exercise*It also produces antioxidants such as superoxide dismutase2 (SOD2), an enzyme that plays a role in clearing mitochondria of ROS and preventing cancer[27]. In addition, exercise also increases the antioxidative capacity in cancer patients[28], which suppresses oxidative stress levels, which are triggers for progressive cancer. Exercise at moderate doses provides benefits in cancer therapy by increasing the performance of NK and CD8+ cells, which affect survival. Meanwhile, in healthy individuals, exercise will increase immune changes in T cells and NK cells[5]. In healthy populations, exercise can inhibit cancer cell growth by inhibiting proliferation and apoptosis in various cancer cell variations. In other words, exercise has an anti-oncogenic effect[19].

Research has also been conducted to examine the role of exercise on testosterone levels, showing that cycling in cancer patients results in decreased testosterone. In general, exercise impacts sex hormone levels and sex hormone receptors. Furthermore, exercise also increases estrogen receptors and decreases androgens. Physical activity interventions in postmenopausal women have been shown to decrease levels of the pro-inflammatory cytokines IL-1α and IL-6.

Chemotherapy treatment results in increased circulating cytokine levels both in the periphery and in the brain and is associated with decreased cognitive function. Although the relationship between cytokine levels and brain-derived factor (BDNF) levels has not been fully explained, BDNF plays a crucial role in cognitive function[9]. Exercise is associated with neurogenesis, increased levels of BDNF, vascular endothelial growth factor (VEGF-1), and cognitive function[29,30,31]. BDNF expression in cells after exercise also influences brain plasticity in both elderly individuals with cognitive impairment and post-stroke patients. Improved immunity also occurs in healthy elderly individuals with comorbidities, with increased expression and ratio of CD4+/CD8+ T-cell helpers and decreased levels of IL-6, IL8, IL1-10, and VEGF[25]. This increased CD4+ expression also occurs in patients with stable chronic obstructive pulmonary disease (COPD)[32].

Improved cardiorespiratory function also occurs after exercise in post-COVID-19 patients and in patients undergoing hemodialysis due to impaired kidney function[33]. Exercise can also be an option for treating chronic kidney disease because improved body composition, bone mineral density, blood pressure, glucose homeostasis, cardiac autonomic function, depressive symptoms, and quality of life will help reduce the risk of kidney function decline[14,34]. This improvement is due to increased regulation of exerkine, a hormone secreted into the circulation in response to exercise[35].

**Exercise and Metabolism**

Obesity is always associated with the emergence of chronic inflammatory diseases including type 2 diabetes mellitus, heart disease and cancer[1,36] which can be seen from the increased levels of cytokines such as TNFα and IL-6 as markers of inflammation in adipose tissue mediated by the role of various macrophages[37,38]. Adipose tissue macrophages (ATM) play a role in poor therapy outcomes for cancer patients[39]. Exercise given to cancer patients shows a decrease in M1 (pro-inflammatory) and an increase in M2 (anti-inflammatory), at the same time exercise also causes a decrease in pro-inflammatory cytokines (IL-6, TNFα) and an increase in anti-inflammatory cytokines (adiponectine, IL-12) and affects HDL cholesterol[39].

Adipose tissue is one of the tissues that adapts to exercise. Obese individuals, both white adipose tissue (WAT) and brown adipose tissue (BAT), experience inflammation[40], characterized by increased inflammatory signals such as nuclear factor-κB (NFκB) and mitogen-activated protein kinases (AMPKs). Exercise training reduces oxidative stress levels and increases antioxidant and anti-inflammatory protein levels in BAT[2].

In type 1 diabetes, exercise is beneficial in reducing the incidence of hypoglycemia and improving glycemic control. This is because exercise plays a crucial role in mitochondrial biogenesis. Increased AMPK activation is crucial in type 1 diabetes and is a key contributor to the benefits of exercise and glucose control[41]. Exercise has also been shown to reduce muscle myokine (TNFα) expression, which contributes to impaired muscle mass in type 1 diabetes and is associated with reduced TNFα levels through reduced oxidative stress[27].

*Exercise*can reduce body fat and visceral adipose tissue (VAT)[36] by improving the dysmetabolism experienced by obese individuals, although exercise cannot be said to be associated with a decrease in inflammatory biomarkers such as CRP, IL-6 and TNFα, this seems to be related to the duration of the exercise intervention which is only 8 weeks[39]. However, resistance training has an effect on the levels of HDL cholesterol, LDL cholesterol, adiponectine, IL-6 and testosterone[42]. The benefits of exercise can increase insulin sensitivity by reducing (down-regulating) adipocyte-produced cytokine signaling[42]. Resisted training combined with aerobic training is useful for improving body composition[40].

The benefits of exercise are also seen when combined with diet. Significant results were also shown when exercise was performed both without diet and with diet. Comparing exercise without diet and with diet showed no difference, meaning that exercise alone still has benefits in reducing the risk of osteoporosis in postmenopausal women[29]. However, the same effect was not observed in older adults who received exercise for 6 weeks[43].

Exercise causes changes in the surface of extracellular vascular bundles that influence circulating miRNAs in paracrine communication. At the same time, it increases stem cell proliferation[44]. Circulating mRNA is crucial for arteriogenesis and improves capillary function[10]. Exercise also stimulates angiogenesis in lower extremity capillaries with peripheral artery disease (PAD) through the expression of microRNA-126, which is involved in VEGF signaling via the PI3K/Akt/eNOS pathway.

Exercise also improves quality of life for the elderly by improving gait patterns and mild cognitive impairment (MCI) experienced by the elderly[31,47]. Quality of life (QOL) also improves in people with chronic diseases such as cancer[48,49] and kidney failure[22]. This improvement in QOL is measured by the incidence of fatigue[48,49,50].

Improvements also occur in patients who receive hematopoietic cell transplantation (HCT) after exercise intervention. The risk of osteopenia, decreased muscle mass, and the development of other chronic diseases is reduced[51,52]. Exercise modulates the environment around the infarct area in stroke patients through angiogenesis, vasomotor reactivity, neutropic factor release, and reduced excitotoxicity and inflammation, which in turn improves neurological function in stroke patients. Exercise enhances graft cell integration in stroke therapy[23].

### Exercise Dosage

*Exercise*While exercise does have an immediate effect on physiological changes in body tissues, its benefits for chronic disease conditions are determined by the frequency, intensity, time, and type (FITT) of exercise[38,53,54]. Frequency is usually calculated in terms of times per week and over months or even years, while intensity is considered based on the target maximum heart rate (MHR). Commonly used heart rate targets are moderate intensity training (MIT)[55] or high intensity training, depending on the desired goal.

The recommended time for each exercise session is a minimum of 45 minutes per day[15] or 150 minutes per week or 5 times per week[54,56–59]. The types of exercise frequently used are aerobic exercise (endurance)[60] and anaerobic exercise (strength/weight exercise) and even interval exercise[5]. Of the majority of muscle contraction types, there are isometric, isotonic, eccentric, and isokinetic[61,62].

## CONCLUSIONS

Exercise as an intervention option for chronic diseases aims to provide prevention, treatment, rehabilitation, and even regenerative benefits. Exercise has been proven to benefit the body and improve quality of life, making it highly recommended for improving health.

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### Ethical Approval

The research received ethical clearance from the Prof. Dr. IGNG Ngoerah Hospital. The approval date is May 28th, 2020, with number 1119/UN14.2.2.VII.14/LT/2020.

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### Conflicts of Interest

There are no conflicts of interest.

## REFERENCES

1. Komori T, Morikawa Y. Essential role of the cytokine oncostatin M in crosstalk between muscle fibers and immune cells in skeletal muscle after aerobic exercise. J Biol Chem. 2022 Dec;102686.
2. Tsuzuki T, Yoshihara T, Ichinoseki-Sekine N, Kobayashi H, Negishi T, Yukawa K, et al. Exercise training improves obesity-induced inflammatory signaling in rat brown adipose tissue. Biochem Biophys Rep. 2022 Dec;32:101398.
3. Tipton CM. The history of "Exercise Is Medicine" in ancient civilizations. Adv Physiol Educ. 2015;38(2):109–17.
4. Georgoulis AD, Kiapidou IS, Velogianni L, Stergiou N, Boland A. Herodicus, the father of sports medicine. Knee Surg Sports Traumatol Arthrosc. 2007;15:315–8.
5. Wu Z, Zhang Z, Zhou Z, Rao S, Li S. Effect of aerobic exercise on lung regeneration and inflammation in mice. Immunobiology. 2022 Nov 1;227(6).
6. Jurado-Fasoli L, Di X, Sanchez-Delgado G, Yang W, Osuna-Prieto FJ, Ortiz-Alvarez L, et al. Acute and long-term exercise differently modulate plasma levels of oxylipins, endocannabinoids, and their analogues in young sedentary adults: A sub-study and secondary analyses from the ACTIBATE randomized controlled trial. 2022.
7. Lovell AJ, Hoecht EM, Hucik B, Cervone DT, Dyck DJ. The effects of diet and chronic exercise on skeletal muscle ghrelin response. Metab Open. 2022 Jun;14:100182.
8. Liu Z, Gong F, Tian L, Yan J, Li K, Tan Y, et al. Acute exercise in ozone-polluted air induces apoptosis in rat quadriceps femoris muscle cells via mitochondrial pathway. Sports Med Health Sci. 2022 Sep 1;4(3):190–7.
9. Ng SY, Mikhail A, Ljubicic V. Mechanisms of exercise-induced survival motor neuron expression in the skeletal muscle of spinal muscular atrophy-like mice. J Physiol. 2019 Sep 1;597(18):4757–78.
10. Tickle PG, Hendrickse PW, Weightman A, Hakam Nazir M, Degens H, Egginton S, et al. Impaired skeletal muscle fatigue resistance during cardiac hypertrophy is prevented by functional overload or exercise-induced functional capillarity. J Physiol. 2021;599:3715–33.
11. Yang W, Liu L, Wei Y, Fang C, Liu S, Zhou F, et al. Exercise suppresses NLRP3 inflammasome activation in mice with diet-induced NASH: a plausible role of adropin. Lab Invest. 2021 Mar 1;101(3):369–80.
12. Yap NY, Toh YL, Tan CJ, Acharya MM, Chan A. Relationship

between cytokines and brain-derived neurotrophic factor (BDNF) in trajectories of cancer-related cognitive impairment. Cytokine. 2021 Aug 1;144.
13. Kim J, Lee S. Maternal low-intensity exercise and probiotic ingestion during pregnancy improve physical ability and brain function in offspring mice. J Funct Foods. 2022 Dec 1;99.
14. de Araújo TB, de Luca Corrêa H, de Deus LA, Neves RVP, Reis AL, Honorato FS, et al. The effects of home-based progressive resistance training in chronic kidney disease patients. Exp Gerontol. 2023 Jan 1;171:112030.
15. Timon R, Martínez-Guardado I, Camacho-Cardeñosa A, Villa-Andrada JM, Olcina G, Camacho-Cardeñosa M. Effect of intermittent hypoxic conditioning on inflammatory biomarkers in older adults. Exp Gerontol. 2021 Sep 1;152.
16. Saadeh M, Prinelli F, Vetrano DL, Xu W, Welmer AK, Dekhtyar S, et al. Mobility and muscle strength trajectories in old age: the beneficial effects of Mediterranean diet in combination with physical activity and social support. Int J Behav Nutr Phys Act. 2021 Dec 1;18(1).
17. Montero-Odasso M, Almeida QJ, Burhan AM, Camicioli R, Doyon J, Fraser S, et al. SYNERGIC TRIAL (SYNchronizing Exercises, Remedies in Gait and Cognition): a multicentre randomized controlled double-blind trial to improve gait and cognition in mild cognitive impairment. BMC Geriatr. 2018 Apr 16;18(1).
18. Winzer BM, Paratz JD, Reeves MM, Whiteman DC. Exercise and the Prevention of Oesophageal Cancer (EPOC) study protocol: a randomized controlled trial of exercise versus stretching in males with Barrett's esophagus. BMC Cancer. 2010;10.
19. Schwappacher R, Schink K, Sologub S, Dieterich W, Reljic D, Friedrich O, et al. Physical activity and advanced cancer: evidence of exercise-sensitive genes regulating prostate cancer cell proliferation and apoptosis. J Physiol. 2020 Sep 1;598(18):3871–89.
20. Berntsen S, Aaronson NK, Buffart L, Börjeson S, Demmelmaier I, Hellbom M, et al. Design of a randomized controlled trial of physical training and cancer (Phys-Can): the impact of exercise intensity on cancer-related fatigue, quality of life and disease outcome. BMC Cancer. 2017 Mar 27;17(1).
21. Hagar A, Wang Z, Koyama S, Serrano JA, Melo L, Vargas S, et al. Endurance training slows breast tumor growth in mice by suppressing Treg cell recruitment to tumors. BMC Cancer. 2019 Jun 4;19(1).
22. Dhillon HM, van der Ploeg HP, Bell ML, Boyer M, Clarke S, Vardy J. The impact of physical activity on fatigue and quality of life in lung cancer patients: a randomized controlled trial protocol. BMC Cancer. 2012 Dec 5;12.
23. Wu R, Guo Y, Zhang L, Zheng H, Chen X, Li M, et al. Physical exercise promotes integration of grafted cells and functional recovery in an acute stroke rat model. Stem Cell Rep. 2022 Feb 8;17(2):276–88.
24. Yang J, Vamvini M, Nigro P, Ho LL, Galani K, Alvarez M, et al. Single-cell dissection of the obesity–exercise axis in adipose-muscle tissues implies a critical role for mesenchymal stem cells. Cell Metab. 2022 Oct 4;34(10):1578–93.e6.
25. Despeghel M, Reichel T, Zander J, Krüger K, Weyh C. Effects of a 6-week low-dose combined resistance and endurance training on T cells and systemic inflammation in the elderly. Cells. 2021 Apr 1;10(4).
26. Wooten JS, Poole KE, Harris MP, Guilford BL, Schaller ML, Umbaugh D, et al. The effects of voluntary wheel running during weight loss on biomarkers of hepatic lipid metabolism and inflammation in C57Bl/6J mice. Curr Res Physiol. 2022;5:63–72.
27. Kotowska J, Jówko E, Cieśliński I, Gromisz W, Sadowski J. IL-6 and HSPA1A gene polymorphisms may influence inflammatory and oxidative stress parameters and their response to chronic swimming training. Int J Environ Res Public Health. 2022 Jul 1;19(13).
28. Zimmer P, Jäger E, Bloch W, Zopf EM, Baumann FT. Influence of a six-month endurance exercise program on immune function of prostate cancer patients undergoing antiandrogen or chemotherapy: design and rationale of the ProImmun study. BMC Cancer. 2013 Jun 3;13.
29. Masala G, Bendinelli B, Della Bella C, Assedi M, Tapinassi S, Ermini I, et al. Inflammatory marker changes in a 24-month dietary and physical activity randomized intervention trial in postmenopausal women. Sci Rep. 2020 Dec 1;10(1).
30. Kim J, Lee S. Maternal low-intensity exercise and probiotic ingestion during pregnancy improve physical ability and brain function in offspring mice. J Funct Foods. 2022 Dec 1;99.
31. Montero-Odasso M, Almeida QJ, Burhan AM, Camicioli R, Doyon J, Fraser S, et al. SYNERGIC TRIAL (SYNchronizing Exercises, Remedies in Gait and Cognition): a multicentre randomized controlled double-blind trial to improve gait and cognition in mild cognitive impairment. BMC Geriatr. 2018 Apr 16;18(1).
32. Uzeloto JS, de Toledo-Arruda AC, Silva BSA, Braz AMM, de Lima FF, Grigoletto I, et al. Effect of physical training on cytokine expression in CD4+ T lymphocytes in subjects with stable COPD. Ther Adv Respir Dis. 2022;16.
33. Figueiredo PHS, Lima MMO, Costa HS, Martins JB, Flecha OD, Gonçalves PF, et al. Effects of inspiratory muscle training and aerobic training on respiratory and functional parameters, inflammatory biomarkers, redox status, and quality of life in hemodialysis patients: a randomized clinical trial. PLoS One. 2018 Jul 1;13(7).
34. Headley SA, Chapman DJ, Germain MJ, Evans EE, Hutchinson J, Madsen KL, et al. The effects of 16 weeks of prebiotic supplementation and aerobic exercise training on inflammatory markers, oxidative stress, uremic toxins, and microbiota in pre-dialysis kidney patients: a randomized controlled trial protocol. BMC Nephrol. 2020 Dec 1;21(1).
35. 35. Nikniaz L, Ghojazadeh M, Nateghian H, Nikniaz Z, Farhangi MA, Pourmanaf H. The interaction effect of aerobic exercise and vitamin D supplementation on inflammatory factors, anti-inflammatory proteins, and lung function in male smokers: a randomized controlled trial. BMC Sports Sci Med Rehabil. 2021;13(1):1–8.
36. McLeod A, Schiffer L, Castellanos K, Demott A, Olender S, Fitzgibbon M, et al. Impact of physical activity and weight loss on fat mass, glucose metabolism, and inflammation in older African Americans with osteoarthritis. Nutrients. 2020 Nov 1;12(11):1–13.
37. Gerber M, Imboden C, Beck J, Brand S, Colledge F, Eckert A, et al. Effects of aerobic exercise on cortisol stress reactivity in response to the Trier Social Stress Test in patients with major depressive disorders: a randomized controlled trial. J Clin Med. 2020;9(5).
38. Komori T, Morikawa Y. Essential role of the cytokine oncostatin M in crosstalk between muscle fibers and immune cells in skeletal muscle after aerobic exercise. J Biol Chem. 2022 Dec;102686.
39. Gerber M, Imboden C, Beck J, Brand S, Colledge F, Eckert A, et al. Effects of aerobic exercise on cortisol stress reactivity in response to the Trier Social Stress Test in patients with major depressive disorders: a randomized controlled trial. J Clin Med. 2020;9(5).
40. Dieli-Conwright CM, Parmentier JH, Sami N, Lee K, Spicer D, Mack WJ, et al. Adipose tissue inflammation in breast cancer survivors: effects of a 16-week combined aerobic and resistance exercise training intervention. Breast Cancer Res Treat. 2018 Feb 1;168(1):147–57.
41. Hawke TJ. Do those with type 1 diabetes need more exercise to maintain skeletal muscle health? J Physiol. 2022 Mar 1;600(6):1281–2.
42. Ahmad I, Zaman G, Silvian S, Alshaharani M, Mansuri N, Fayazuddin S. Resistance training exercises for obese and non-obese individuals living in high-altitude regions utilizing biochemical markers: a controlled trial. 2021.
43. Banitalebi E, Ghahfarrokhi MM, Dehghan M. Effect of 12 weeks elastic band resistance training on MyomiRs and osteoporosis markers in elderly women with osteosarcopenic obesity: a randomized controlled trial. BMC Geriatr. 2021 Dec 1;21(1).
44. Just J, Yan Y, Farup J, Sieljacks P, Sloth M, Venø M, et al. Blood flow–restricted resistance exercise alters the surface profile, miRNA cargo, and functional impact of circulating extracellular vesicles. Sci Rep. 2020 Dec 1;10(1).
45. Vogel J, Niederer D, Engeroff T, Vogt L, Troidl C, Schmitz-Rixen T, et al. Effects on the profile of circulating miRNAs after single bouts of resistance training with and without blood flow restriction: a three-arm randomized crossover trial. Int J Mol Sci. 2019 Jul 1;20(13).
46. da Silva ND, Andrade-Lima A, Chehuen MR, Leicht AS, Brum PC, Oliveira EM, et al. Walking training increases microRNA-126 expression and muscle capillarization in patients with peripheral artery disease. Genes (Basel). 2023 Jan 1;14(1).
47. 47. Yap NY, Toh YL, Tan CJ, Acharya MM, Chan A. Relationship between cytokines and brain-derived neurotrophic factor (BDNF) in trajectories of cancer-related cognitive impairment. Cytokine. 2021 Aug 1;144.

48. Berntsen S, Aaronson NK, Buffart L, Börjeson S, Demmelmaier I, Hellbom M, et al. Design of a randomized controlled trial of physical training and cancer (Phys-Can): the impact of exercise intensity on cancer-related fatigue, quality of life and disease outcome. BMC Cancer. 2017 Mar 27;17(1).
49. Twomey R, Martin T, Temesi J, Culos-Reed SN, Millet GY. Tailored exercise interventions to reduce fatigue in cancer survivors: study protocol of a randomized controlled trial. BMC Cancer. 2018 Jul 24;18(1).
50. Dhillon HM, van der Ploeg HP, Bell ML, Boyer M, Clarke S, Vardy J. The impact of physical activity on fatigue and quality of life in lung cancer patients: a randomized controlled trial protocol. BMC Cancer. 2012 Dec 5;12.
51. Song M, Armenian SH, Bhandari R, Lee K, Ness K, Putt M, et al. Exercise training and NR supplementation to increase muscle mass and fitness in adolescent and young adult hematopoietic cell transplant survivors: a randomized controlled trial. BMC Cancer. 2022 Dec 1;22(1).
52. Wiskemann J, Kuehl R, Dreger P, Huber G, Kleindienst N, Ulrich CM, et al. Physical exercise training versus relaxation in allogeneic stem cell transplantation (PETRA Study): rationale and design of a randomized trial to evaluate a yearlong exercise intervention on overall survival and side effects after allogeneic stem cell transplantation. BMC Cancer. 2015 Sep 7;15(1).
53. Wu Z, Zhang Z, Zhou Z, Rao S, Li S. Effect of aerobic exercise on lung regeneration and inflammation in mice. Immunobiology. 2022 Nov 1;227(6).
54. Hawke TJ. Do those with type 1 diabetes need more exercise to maintain skeletal muscle health? J Physiol. 2022 Mar 1;600(6):1281–2.
55. Teeman CS, Kurti SP, Cull BJ, Emerson SR, Haub MD, Rosenkranz SK. The effect of moderate-intensity exercise in the postprandial period on the inflammatory response to a high-fat meal: an experimental study. Nutr J. 2016 Mar 8;15(1).
56. Wu R, Guo Y, Zhang L, Zheng H, Chen X, Li M, et al. Physical exercise promotes integration of grafted cells and functional recovery in an acute stroke rat model. Stem Cell Rep. 2022 Feb 8;17(2):276–88.
57. Winzer BM, Paratz JD, Reeves MM, Whiteman DC. Exercise and the Prevention of Oesophageal Cancer (EPOC) study protocol: a randomized controlled trial of exercise versus stretching in males with Barrett's esophagus. BMC Cancer. 2010;10.
58. Timon R, Martínez-Guardado I, Camacho-Cardeñosa A, Villa-Andrada JM, Olcina G, Camacho-Cardeñosa M. Effect of intermittent hypoxic conditioning on inflammatory biomarkers in older adults. Exp Gerontol. 2021 Sep 1;152.
59. McLeod A, Schiffer L, Castellanos K, Demott A, Olender S, Fitzgibbon M, et al. Impact of physical activity and weight loss on fat mass, glucose metabolism, and inflammation in older African Americans with osteoarthritis. Nutrients. 2020 Nov 1;12(11):1–13.
60. Wiskemann J, Kuehl R, Dreger P, Huber G, Kleindienst N, Ulrich CM, et al. Physical exercise training versus relaxation in allogeneic stem cell transplantation (PETRA Study): rationale and design of a randomized trial to evaluate a yearlong exercise intervention on overall survival and side effects after allogeneic stem cell transplantation. BMC Cancer. 2015 Sep 7;15(1).
61. Nambi G, Abdelbasset WK, Alsubaie SF, Moawd SA, Verma A, Saleh AK, et al. Isokinetic training: its radiographic and inflammatory effects on chronic
62. Merza EY, Pearson SJ, Lichtwark GA, Malliaras P. The acute effects of higher versus lower load duration and intensity on morphological and mechanical properties of the healthy Achilles tendon: a randomized crossover trial. Journal of Experimental Biology. 2022 May 1;225(10).