THE EFFECTS OF COMBINING AEROBIC AND HYPERTROPHY ORIENTED RESISTANCE TRAINING ON BODY COMPOSITION, MUSCLE HYPERTROPHY AND EXERCISE SATISFACTION IN PHYSICALLY ACTIVE ADULTS

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TABLE OF CONTENTS

APPENDICES

APPENDIX D: ETHICAL CONSENT FORM

APPENDIX E: EXERCISE PICTURES

APPENDIX F: TRAINING PICTURES

APPENDIX G: PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

APPENDIX H: BODY COMPOSITION SCAN

APPENDIX I: WORKOUT SHEETS

APPENDIX J: PROGRESS SHEET

APPENDIX K: BEFORE & AFTER PICTURES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACE	American Council on Exercise
ACSM	American College of Sports Medicine
BIA	Bioelectrical Impedance Analysis
BMD	Bone Mineral Density
BMI	Body Mass Index
CI	Confidence Interval
cm	Centimetres
DF	Degree of Freedom
HIIT	High-Intensity Interval Training
ID	Intellectual Disabilities
kcal	Kilocalories
kg	Kilograms
MCO	Movement Control Order
MD	Mean Difference
MOH	Ministry of Health
NCD	Non-communicable diseases
NSCA	National Strength & Conditioning Association
PACES	Physical Activity Enjoyment Scale
PAR-Q	Physical Activity Readiness Questionnaire
RM	Repetition Maximum
RMR	Resting Metabolic Rate
SPSS	Statistical Product and Service Solution
USD	United States Dollar
USM	Universiti Sains Malaysia
WHO	World Health Organization

LIST OF APPENDICES

KESAN KOMBINASI LATIHAN AEROBIK DAN RINTANGAN BERORIENTASIKAN HIPERTROFI TERHADAP KOMPOSISI BADAN, HIPERTROFI OTOT DAN KESERONOKAN SENAMAN DALAM KALANGAN DEWASA YANG AKTIF SECARA FIZIKAL

ABSTRAK

Kajian ini mengkaji kesan kombinasi latihan aerobik dan latihan rintangan berorientasikan hipertrofi terhadap komposisi badan, hipertrofi otot, dan keseronokan senaman dalam kalangan dewasa yang aktif secara fizikal. Sejumlah 22 orang dewasa lelaki yang sihat dan aktif fizikal dalam kumpulan umur antara 18 hingga 35 tahun yang sebelum ini tidak pernah menjalani latihan hipertrofi otot telah mengikuti program ini. Mereka secara rawak dibahagikan kepada dua kumpulan: kumpulan latihan rintangan dan kumpulan kombinasi (latihan rintangan dan latihan aerobik). Latihan rintangan terdiri daripada pembahagian kumpulan otot selama tiga hari (2–3 latihan setiap kumpulan otot, 8 set setiap kumpulan otot, 6–12 RM), manakala latihan aerobik terdiri daripada program latihan interval aerobik tiga kali seminggu. Kedua-dua kumpulan telah menjalani 8 minggu intervensi latihan, satu kumpulan hanya melakukan latihan rintangan dan kumpulan lain melakukan kombinasi latihan rintangan bersama latihan aerobik, di mana pada akhirnya pembolehubah komposisi badan, hipertrofi otot, dan kepuasan senaman dianalisis secara statistik menggunakan perisian SPSS 27.0. Bagi pembolehubah komposisi badan, latihan kombinasi menunjukkan pengurangan berat badan, peratusan lemak badan, jisim lemak dan peningkatan jisim badan tanpa lemak dalam kumpulan tersebut. Bagi pembolehubah hipertrofi otot, saiz dada telah meningkat dalam kedua-dua kumpulan latihan rintangan tunggal dan latihan kombinasi. Saiz bahu dan saiz pinggul telah meningkat secara signifikan dalam kumpulan latihan rintangan tunggal tanpa peningkatan dalam kumpulan latihan kombinasi. Kumpulan latihan kombinasi telah meningkatkan saiz peha tanpa peningkatan dalam pembolehubah ini diperhatikan dalam kumpulan latihan rintangan. Secara keseluruhan, tidak mungkin untuk menyatakan dengan pasti bahawa satu modaliti latihan lebih unggul daripada yang lain dalam kluster komposisi badan dan hipertrofi otot. Keseronokan senaman telah meningkat dari pra-ujian hingga pasca-ujian dalam kedua-dua kumpulan. Dari pra-ujian ke pasca-ujian, kedua-dua kumpulan intervensi telah meningkatkan keseronokan senaman (keduanya pada $p < 0.05$). Walau bagaimanapun, tiada perbezaan antara kumpulan (latihan rintangan berbanding latihan kombinasi sebelum intervensi dan selepas latihan; ($p > 0.05$). Kesimpulannya, latihan aerobik boleh ditambahkan ke dalam rutin hipertrofi otot tanpa risiko mengurangkan kesan hipertrofi otot. Peningkatan keseronokan senaman menandakan bahawa walaupun dianggap monoton, latihan aerobik apabila ditambahkan ke dalam rutin hipertrofi otot, keseronokan senaman meningkat dengan ketara.

THE EFFECTS OF COMBINING AEROBIC AND HYPERTROPHY ORIENTED RESISTANCE TRAINING ON BODY COMPOSITION, MUSCLE HYPERTROPHY AND EXERCISE SATISFACTION IN PHYSICALLY ACTIVE ADULTS

ABSTRACT

This study investigated the effects of combined aerobic and heavy resistance training on body composition, muscle hypertrophy, and exercise satisfaction in physically active adults in comparison to heavy resistance (hypertrophy-aimed) training alone. A total of 22 healthy, physically active male adults between the ages of 18 and 35 who did not practise muscle hypertrophy training before completed the programme. They were randomly assigned to two groups: the resistance training group and the combined group (resistance training and aerobic training). Resistance training consisted of a three-day muscle group split (2–3 exercises per muscle group, 8 sets per muscle group, 6–12 RM), while aerobic training consisted of a three-times-per-week aerobic interval training programme. Both groups were exposed to 8 weeks of training interventions, one group to resistance training alone and another to a combined training of resistance training plus aerobic training, at the end of which variables of body composition, muscle hypertrophy, and exercise satisfaction were statistically analysed using SPSS 27.0 software. For body composition variables, combined training shows reduction in bodyweight, body fat, fat mass and increment in lean body mass within the group. For muscle hypertrophy variables, chest girth has improved within each the resistance training only and combine training. Shoulder girth and hips girth improved significantly within the resistance training only group with no improvements in the combined group. The combined training group improved in the thighs girth with no

improvement of this variable observed in the resistance training group. Overall, it is impossible to state unequivocally that one training modality was superior to another in the body composition and muscle hypertrophy cluster. Exercise satisfaction has improved from the pre-test to the post-test within the groups. From pre- to post-testing, both intervention groups improved exercise satisfaction (both at $p < 0.05$). There was, however, no difference between the groups (resistance training versus combined training before the intervention and after the training; ($p > 0.05$). In conclusion, aerobic training can be added to muscle hypertrophy routines without the risk of decreasing the effects of muscle hypertrophy. Increased exercise satisfaction signalizes that although deemed monotonous, aerobic workouts when added to hypertrophy routines, exercise satisfaction improves significantly.

CHAPTER 1

INTRODUCTION

Many exercisers opt to combine aerobic training with resistance training because this approach offers a multitude of benefits that cater to various fitness goals. Aerobic exercise, such as running or cycling, enhances cardiovascular health, burns calories, and improves endurance, making it ideal for those aiming to reduce body fat or enhance their overall stamina. On the other hand, resistance training, involving weights or bodyweight exercises, helps build muscle mass, increase strength, and boost metabolism, making it essential for individuals seeking to build muscle, improve strength, or increase daily energy expenditure. When combined, these two forms of exercise create a synergy that promotes overall fitness, leading to improved body composition, increased muscle mass, and better overall health. Additionally, the diversity in workouts can keep individuals motivated and prevent the monotony often associated with single-mode training, making it a popular choice for those looking for a well-rounded and sustainable fitness routine.

1.1 Overview

Participating in regular physical activity has been linked to a lower incidence of a number of chronic diseases, such as diabetes, obesity, and several cancers (Mohamadian & Arani, 2014). Physical inactivity has been linked to 9% of fatalities worldwide (Lee et al., 2012) and has been found to be more common in Malaysian populations (Chai, Kueh, Yaacob, & Kuan, 2019). Around 53.8 billion USD were lost by health care systems worldwide in 2013 as a result of insufficient physical activity (Ding et al., 2016). Therefore, it is considered that a lack of physical activity is a substantial risk factor for mortality worldwide, placing a tremendous financial strain on national health care systems (Memon et al., 2021). Additionally, physically active individuals tend to be healthier, injury-free, and more productive in the workplace than physically inactive people; they also miss less work or office time due to illness and use sick days less frequently (Knapik, 2015).

Aerobic physical fitness also appears to be related to cognitive functioning (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009). Physical fitness is linked to a lower risk of metabolic risk factors (Jago et al., 2010), a lower risk of becoming overweight in adolescence (Moreira et al., 2011), and a lower risk of cardiovascular disease risk clustering (Andersen et al., 2008). When compared to their peers, who are usually developing, adolescents and children with intellectual disabilities (ID) have lower levels of cardiovascular fitness and muscular strength, which may have an adverse effect on their physical and cognitive development (Hillman et al., 2009).

The decrease of muscle mass (sarcopenia) and the morphological and biochemical changes to the skeletal muscle have a profound and detrimental impact on everyday independence, making them of particular concern. After the age of 40, it is predicted that, on average, 5% of muscle mass is lost (Bruseghini et al., 2015). Independent of any long-term endurance training regimen, there appears to be a specific age-related loss of muscle fibres (Toth, Matthews, Tracy, & Previs, 2005), with a selective loss of Type-II fibres and a shift to a greater proportion of sluggish, oxidative Type-I fibres. The effectiveness of our muscles declines if we don't exercise regularly. Therefore, daily physical activity is essential. Exercise has been connected to numerous physiological and physical advantages that improve one's health and ability to perform (Elmagd, 2016).

Health-related fitness behaviours can enhance well-being, increase strength, and delay numerous ageing effects (Elmagd, 2016). Exercise has several benefits, including improved emotional and physical health. In order to promote health and delay or avoid common musculoskeletal disorders like mechanical low back pain, neck pain, and shoulder pain, routine physical activity is still a crucial behaviour (Carlson, Fulton, Schoenborn, & Loustalot, 2010; Piercy et al., 2018). You can maintain or enhance muscle mass and strength by engaging in muscle-strengthening exercises. By maintaining joints in the right position, strong muscles and ligaments minimise your chance of developing joint and lower back pain. Aerobic exercises, including cycling, brisk walking, swimming, skipping rope, rowing, and trekking, can also enhance the circulatory and respiratory systems and promote better oxygen and glucose delivery to the muscles (Elumalai & Ezzeddin, 2016; Greenfield, 2020; Millner, Hardoon, & Lindsay, 2022).

1.2 Problem Statement

The research problem addressed in this study arises from the need to better understand the complex interplay between aerobic and hypertrophy-oriented resistance training and their effects on body composition, muscle hypertrophy, and exercise satisfaction in physically active adults. Muscle hypertrophy is known to significantly impact metabolic rate (Martel et al., 2006), In fact, the scientific estimation of the metabolic rate of muscle is about 10 to 15 kcal/kg per day, which is approximately 4.5 to 7.0 kcal/lb per day (Elia, Stubbs, & Henry, 1999). The majority of peer-reviewed resistance training studies (lasting from 8 to 52 weeks) show increases of 2.2 to 4.5 lbs of muscle mass resulting from such interventions (Donnelly & Lambourne, 2011). This indicate that the increase of 4.5 pounds of muscle mass would increase the resting metabolic rate by about 50 kilocalories per day.

Aerobic endurance training also increases caloric expenditure (Garber et al., 2011) and thus contributes to fat loss. But there is a common belief that aerobic endurance training has limited impact on muscle hypertrophy due to its association with catabolic pathways compared to anaerobic resistance training's anabolic pathways (Atherton et al., 2005; Coffey & Hawley, 2017). This belief has led to the AMPK–phosphatidylinositol 3-kinase (AKT) switch hypothesis, suggesting that aerobic and anaerobic exercises produce opposing signaling responses. However, this theory may oversimplify the relationship between exercise modalities, as recent studies have shown increased mTOR activation following aerobic endurance exercise and consistent AMPK activation after resistance training.

Although deemed monotous, adding aerobic training to hypertrophy oriented training may also help individuals maintain motivation and alleviate the monotony typically associated with singular training methods, rendering it a favored option for those seeking a comprehensive and enduring fitness regimen.

Given the potential metabolic benefits of muscle hypertrophy, benefits of aerobic training in fat loss and how multi-modality can enhance exercise adherence, it is essential to explore how combining aerobic and resistance training influences these variables. This research thesis seeks to address these complexities and contradictions by examining how the combination of aerobic and hypertrophy-oriented resistance training influences body composition, muscle hypertrophy, and exercise satisfaction in physically active adults. The investigation aims to contribute valuable insights into optimizing training strategies for overall health and fitness.

1.3 Significance of the study

The results of the study will give information on the impact of combining heavy resistance training with aerobic exercise on body composition, muscle hypertrophy and exercise satisfaction. Experts in the field of exercise and health professionals may be able to better design programmes to help physically active adults build muscle strength and reduce fat more effectively with the information collected from this study.

1.4 Research Questions

1. What is the effect of combining aerobic and hypertrophy oriented resistance training on body composition?

2. What is the effect of combining aerobic and hypertrophy oriented resistance training on muscle hypertrophy?

3. What is the effect of combining aerobic and hypertrophy oriented resistance training on exercise satisfaction?

1.5 Objectives of the study

1.5.1 General objective of the study

The study's general objective was to investigate the effects of combining aerobic and hypertrophy oriented resistance training on body composition, muscle hypertrophy and exercise satisfaction in physically active adults.

1.5.2 Specific objectives

1. To assess the effects of combined aerobic and heavy resistance training on body composition in physically active adults.
2. To assess the effects of combined aerobic and heavy resistance training on muscle hypertrophy in physically active adults.
3. To assess the effects of combined aerobic and heavy resistance training on exercise satisfaction in physically active adults.

1.6 Research hypotheses

H01: There is no significant effect of combining aerobic training and heavy resistance training on body composition.

HA1: There are significant effects of combining aerobic training and heavy resistance training on body composition.

H02: There is no significant effect of combining aerobic training and heavy resistance training on muscle hypertrophy.

HA2: There are significant effects of combining aerobic training and heavy resistance training on muscle hypertrophy.

H03: There is no significant effect of combining aerobic training and heavy resistance training on exercise satisfaction.

HA3: There are significant effects of combining aerobic training and heavy resistance training on exercise satisfaction.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Blair and Morris (2009) identified physical exercise as the biggest public health issue of the twenty-first century. Non-communicable diseases (NCD) can develop as a result of inadequate physical activity, tobacco use, a poor diet, and excessive alcohol consumption. Sedentary habits like prolonged sitting could soon be added to this list (Dunstan, Thorp, & Healy, 2011). As the biggest global health burden, deaths from NCDs, often known as chronic diseases, have now surpassed communicable diseases (Alleyne et al., 2013). Cardiovascular disease, cancer, diabetes, and chronic respiratory diseases cause the bulk of NCD-related deaths (Nulu, 2017). According to WHO (2018), chronic diseases account for 71% of all deaths, affecting an estimated 41 million people annually.

Around three-quarters of the Malaysian adult population are physically active. Since 2010, there has been growth in physical activity and health research (Khoo, Poh, Suhaimi, Chong, & Varela, 2020). Most studies are observational in design, and few include objective measures of physical activity (Teh et al., 2014). The Malaysian Ministry of Health (MOH) has published physical activity guidelines, strategies, and action plans, all of which serve to promote physical activity. These promotion activities have included national campaigns and programmes that target different populations (Chan et al., 2017). According to a survey on gym memberships by Rakuten Insight (https://insight.rakuten.com/inquiry/), around 49 percent of respondents in Malaysia stated that they went to the gym several times per week. Other common forms of physical activity among Malaysians include recreational activities such as walking, hiking, and cycling. In terms of sport, Malaysia's top sports include football, badminton, takraw (the official national sport of Malaysia), rugby, and hockey.

According to the World Health Organization (WHO), non-communicable diseases (NCDs) are a serious health issue and were responsible for 68% of all deaths worldwide (WHO, 2018). Of these, 42% occurred prematurely, that is, before the age of 70. More than 80% of fatalities occur in developing and middle-income nations. NCDs are a prominent cause of death in Malaysia, which is regarded as an upper-middle-income nation with an estimated population of 32.6 million (Kuala Lumpur Department of Statistics 2019). Rapid socioeconomic development and urbanisation have had a significant impact on Malaysians' way of life and contributed to an increase in NCDs (MOH Malaysia 2016). According to data from the Ministry of Health Annual Reports, disorders of the circulatory system were the leading causes of death from 2010 to 2018 and were responsible for between 22 and 26% of deaths (MOH Malaysia 2011–2019). Population health surveys have been conducted, and the results show an increasing trend in the prevalence of NCDs like diabetes mellitus and hypercholesterolemia, as well as NCD risk factors. While cancers were also among the five leading causes of death during this time period, accounting for between 11 and 14% of deaths, these NCDs are now more common (MOH 2011, 2015). According to the most recent statistics, diabetes, hypertension, and high cholesterol are the three main NCD risk factors that affect about 1.7 million Malaysians (Institute of Public Health 2019).

2.2 Comprehensive Exercise Programme

Physical activity has previously been shown to have numerous positive health effects. People would undoubtedly say "yes" emphatically if asked if they would like to obtain these benefits that will improve their quality of life. However, the 2018 guidelines reminded us that knowledge alone is not enough; action must also be taken, a decade after the US Department of Health and Human Services published the Physical Activity Guidelines for Americans (Piercy et al., 2018).

Benefits of exercise include improved health, fitness, mood, weight management, stress management and other health-related parameters (ACE, 2020). According to American College of Sports Medicine, an effective exercise program should encompass various health-related physical fitness components such as cardiorespiratory fitness, muscular strength and endurance, flexibility, body composition, and neuromotor fitness. Additionally, skill-related physical fitness elements like agility, coordination, balance, power, reaction time, and speed can be incorporated. It is advisable for everyone to include activities aimed at enhancing aerobic fitness, muscular strength, and flexibility. Neuromotor exercises, which encompass skill-related components, are especially recommended for individuals at higher risk of falling, notably older adults, although younger individuals can also benefit. Furthermore, for clients with specific sport or competitive goals, addressing skill-related components becomes essential. The FITT-VP principles of exercise prescription enable a comprehensive design, considering frequency, intensity, time (or duration), type (or mode) of exercise, overall volume, and progression.

2.3 Simultaneous Strength and Endurance Training

Quite often, individuals undertake aerobic endurance and resistance training programmes simultaneously. While the benefits of both are clear, and there is no doubt that both should be part of a complete training program, there is a downside to combining these two different types of training. Research has shown that when properly designed resistance training and aerobic endurance training programmes are combined, the increase in strength gains will be blunted while VO_2 increases normally (Arena & Cahalin, 2014). Individuals will see increases in aerobic endurance similar to those they would have seen if they had done only aerobic endurance training, but the increases in strength from the resistance training portion of their programme will be smaller than if they had done only resistance training (Bruseghini et al., 2015; Ciccolo et al., 2010; Coffey & Hawley, 2017). In addition to lower maximum strength gains, combined programmes result in lower muscle girth gains and specific speed and power-related performances (Ciccolo et al., 2010). On the other hand, the addition of anaerobic resistance training to an aerobic endurance training programme seems to improve low-intensity aerobic endurance (Hillman et al., 2009).

A relatively sedentary individual who is just beginning to exercise will show improvements from both aerobic and resistance training when using both programmes within a total workout (Knapik, 2015). However, for more advanced individuals who are reaching plateaus in improvement, it is doubtful that they will obtain the full benefits of both programs at the same time because there will be little to no recovery time (days off to rest) (Knapik, 2015).

To remedy this problem, most personal trainers design a programme to allow their clients to complete the aerobic endurance training programme before beginning the resistance training program. For instance, a client could perform eight weeks of only aerobic endurance training, followed by eight weeks of only resistance training, with only the minimal amount of aerobic endurance training needed for maintenance. This would allow the client to increase VO2max and establish an aerobic base first, then work on increasing muscular fitness (e.g., strength) while maintaining the improved VO_2 (Bell, Syrotuik, Attwood, & Quinney, 1993; Griffiths & McConnell, 2007). After the initial 16 weeks, the client could begin alternating periods of aerobic endurance training and minimal resistance training for maintenance of strength with periods of resistance training and minimal aerobic endurance. training for maintenance of aerobic endurance (Hillman et al., 2009). This style of programme provides continued increases in both aerobic endurance and muscular strength, although at a reduced rate in comparison to training only for one or the other, and also allows for changes in programme variables such as mode and intensity to enhance variety.

2.4 Existing Training Modalities of Combined Training

Combined training can be performed in the same session as aerobic and resistance training (e.g., circuit training) or on a separate session (in a weekly split, days are allocated for both resistance and aerobic training). Circuit training combines resistance training with aerobic endurance training. Exercisers perform short intervals of aerobic endurance training between resistance training sets. The goal is to raise your heart rate to the training zone and stay there. Unfortunately, most investigations on variations of circuit training have shown that although strength increased, VO2max did not significantly improve compared to values for participants in an aerobic exercise–only programme or a combined circuit training and aerobic programme (Hollings, Mavros, Freeston, & Fiatarone Singh, 2017; Vromen et al., 2016). Those research studies that did show small improvements in VO2max due to circuit training required the subjects to train at heart rates close to 90% HRR (Vromen et al., 2016).

Combining high-intensity aerobic and high-intensity resistance training modalities into a single time-efficient exercise session may help individuals fulfil the current physical activity recommendations and has recently gained interest (Kercher et al., 2021). For example, high-intensity interval training (HIIT), bodyweight, functional fitness, and group training are among the top 20 worldwide fitness trends for 2021 (Kercher et al., 2021). There have been recent attempts to label and define this emerging training trend using terms such as high-intensity functional training (HIFT), CrossFit®, bodyweight HIIT, resistance HIIT, and circuit high-intensity interval training (Batrakoulis, Jamurtas, & Fatouros, 2021).

Combining high-intensity aerobic and high intensity resistance training modalities into a single time-efficient exercise session may contain similar components to HIIT, which typically involves a single aerobic exercise mode (i.e., cycling or running). Both may be characterised by repeated bouts of high- or vigorous-intensity activity interspersed with periods of active or passive rest (Batrakoulis et al., 2021). The current popularity of HIIT training can be largely attributed to its ability to elicit significant training adaptations in a time-efficient manner (Batrakoulis et al., 2021). Concurrent training in a single session may also be an appealing exercise method for combining aerobic and resistance training into a single session. Previous studies have attempted to investigate the chronic or long-term (i.e., ≥ 4 weeks) health and fitness outcomes of combining high intensity aerobic and high intensity resistance training (Batrakoulis et al., 2021; Gillen & Gibala, 2018). These studies suggest that the combination of high-intensity aerobic and high intensity resistance training elicits time-efficient aerobic and muscular fitness adaptations (Faelli et al., 2020; Nichols, Engin, Carroll, Buckley, & Ingle, 2020). However, due to the limited ability to prescribe, control, and monitor high or vigorous levels of intensity and difficulties in standardising external work, it remains unclear whether this modality is as effective as other concurrent aerobic and resistance training interventions (Faelli et al., 2020), for example, combined training where aerobic and resistance exercise are distributed into separate training blocks within a single session or on different days.

2.5 Relationship between Exercise Modalities and Exercise Satisfaction

The relationship between exercise modality (the type or form of exercise) and exercise satisfaction is complex and varies from person to person. Some research suggests genetic variations might even determine how enjoyable a person perceives exercise to be (Huppertz et al., 2014). For those who once enjoyed being active more likely to enjoy it again, and those with negative past experiences being active more prone to additional negative experiences. Because how exercise impacts mood in the moment and directly after is a strong predictor of exercise adherence (Ekkekakis, Parfittt, & Petruzzello, 2011) identifying how exercise is making someone feel is very important. Exercise can be experienced as pleasant or unpleasant, can create feelings of tension or relaxation and can make the exerciser feel energetized or tired. One study found that a cycling workout that started at a high intensity but slowly reduced in intensity over time was more effective at generating positive mood relative to a workout that started at a low intensity and increased to a high intensity (Zenko, Ekkekakis, & Ariely, 2016).

People have different preferences when it comes to exercise. Some may enjoy activities like running, while others prefer group fitness classes, weightlifting, swimming, yoga, or team sports. Satisfaction with exercise often depends on whether the chosen modality aligns with an individual's personal preferences and interests. (ACE, 2019)

Exercise satisfaction can be closely tied to one's fitness goals. If a person's goal is to build strength, they may find satisfaction in weightlifting or resistance training. If the goal is stress relief and relaxation, activities like yoga or meditation may be more satisfying. Matching the exercise modality to specific goals can enhance satisfaction (ACE, 2019)

An individual's physical condition and health status play a significant role in determining which exercise modalities are suitable and satisfying. Some individuals may have physical limitations or medical conditions that restrict their choices, making it important to find exercises that are safe and accommodating (ACE, 2019)

Psychological factors, including motivation, self-efficacy, and mindset, influence exercise satisfaction. People who feel confident in their ability to perform a certain type of exercise and who enjoy the mental benefits it offers are more likely to find satisfaction in that modality (ACE, 2019). A review of literature suggests that continuous self-monitoring by an exerciser of how pleasant/unplesasant the exercise is should guide changes in intensity, such that intensity is lowered in response to the emergence of unpleasant mood (Ekkekakis, Parfitt, & Petruzzello, 2011)

Some individuals may find exercise satisfaction by incorporating variety into their routine. Trying different exercise modalities can prevent boredom and maintain motivation. Cross-training, which involves mixing different forms of exercise, can be particularly satisfying for those who enjoy diversity (ACE, 2019)

For some, exercise satisfaction is closely tied to social interaction. Activities like team sports, group fitness classes, or exercising with friends can provide a sense of community and enhance overall satisfaction. (ACE, 2019). Environmental Factors: The exercise environment can also impact satisfaction. Some individuals prefer indoor settings like gyms, while others enjoy outdoor activities like hiking or cycling. The surroundings and ambiance can influence how satisfying an exercise modality feels. (ACE, 2019) Another study found that music and video distraction during workouts was associated with positive mood, regardless of intensity level (Jones, Karageorghus, & Ekkekakis, 2014).

2.6 Effects of Simultaneous Strength and Endurance Training on Body Composition, Muscle Hypertrophy, and Exercise Satisfaction

Aerobic exercise is often performed in combination with resistance training for accelerating fat loss and has been shown to have a positive effect on weight management (Sanches et al., 2014). However, evidence suggests that the addition of aerobic exercise to a regimented resistance training program may compromise muscle growth. Like the AMPK–Akt switch hypothesis, the chronic interference hypothesis states that these competing adaptations produce divergent intracellular signalling responses that mitigate muscular gains (Atherton et al., 2005; Jung & Song, 2018).

One of the interference characteristics of the combined training is a lack of muscle hypertrophy (Aube et al., 2022; Bell et al., 1993). The adaptations to strength, and endurance training show different neural responses in terms of muscle fibre recruitment. It appears that concurrent strength and endurance training may hinder the organisation of efficient motor unit recruitment patterns necessary for forceful muscular contractions at the level of the peripheral or central nervous system

(Cardinale et al., 2011). The hypertrophy of certain muscle fibres is likely to be limited by the lack of neural stimulation, which is associated with the training of strength only. Several of the studies showed compromises in strength (Kraemer et al., 2017; Lee et al., 2012; Miller et al., 2018), though it is not exactly clear what the mechanism(s) are that cause the compromises. From the studies reviewed, the impact of combined training appears to be more detrimental to potential strength and power gains than to VO_2max.

The majority of concurrent training studies have been carried out with untrained subjects, making it difficult to extrapolate conclusions to physically active people. The few studies that have used subjects with exercise training experience show that those who are well trained have less interference. Kraemer et al. (2017) investigated the compatibility of aerobic and resistance exercise in a group of army recruits involved in standard military training for at least 3 days per week for 2 years before the onset of the study. Subjects were randomly assigned to perform aerobic endurance exercise, resistance exercise, or concurrent training. The aerobic endurance protocol consisted of a combination of steady-state and high-intensity interval training. After 8 weeks, subjects in the resistance-only group displayed increases in Type I, Type IIA, and Type IIC fibre diameters, whereas those in the concurrent group showed significant increases only in Type IIA fibres. Also, Ferreira et al. (2012) found similar results in a group of physically active university students, at least some of whom had experience in strength and aerobic endurance training. Subjects performed 8 weeks of cycle ergometry, resistance training, or a combination of both modalities. Results showed that resistance training only increased both Type I and Type II fibre cross-sectional area, whereas concurrent training produced increases only in Type II fibres. Moreover, the magnitude of Type II fibre hypertrophy was markedly greater in the resistance-only group compared to those who performed concurrent training (28% vs. 14%, respectively). Taken together, these findings suggest that concurrent training may be particularly detrimental to well-trained individuals.

Also, consideration must be given to the relatively short duration of most concurrent training studies. Wilson et al. (2012) found no evidence of interference in a combined aerobic and resistance training protocol until the 8th week of training. This finding indicates that negative effects on hypertrophy may not manifest for months, but ultimately long-term increases in muscle size may be compromised, conceivably as a result of non-functional overreaching or overtraining. Combining resistance and aerobic training has been shown to increase exercise satisfaction and intrinsic motivation, contributing to greater exercise adherence. This will play a role in the improvement of health and fitness (Pöchmüller et al., 2016; Wilson et al., 2012).

2.7 Resistance Training Modalities

There are many training modalities for resistance training. They are often designed and prescribed according to the objective of use (Kaesler, Mellifont, Kelly, & Taaffe, 2007). Some can be described as follows:

i. To help re-establish neural control and maintain good joint position, the American Council on Exercise (ACE) recommends low-grade isometric exercises followed by low-load, higher-volume dynamic movements.
ii. To help improve movement efficiency and establish good coordination between the skeletal, muscular, and neural systems, the American Council on Exercise (ACE) recommends exercisers perform the five basic human movements (bend and lift, single leg, push, pull, and rotation) in all three planes (sagittal, frontal, and transverse).

iii. For exercisers with reasonable exercise techniques, they can progress their resistance training programme by loading the movements to achieve muscular benefits, namely, muscular endurance, muscular strength, and muscular hypertrophy.

iv. Muscular endurance is the ability to perform more repetitions given a load in order to increase a muscle's work duration. The National Strength & Conditioning Association (NSCA) recommends low loads (67% 1RM) and high repetitions (≥12 RM) to achieve this benefit.

Training modalities can also differ depending on the variables of load and recovery. The following variables are recommended by the American Council on Exercise (ACE) (Kaesler et al., 2007).

i. *Frequency:* At this point, the variables of programme design can be adjusted to provide varying levels of training stimulus. During the initial months of a standard strength-training program, two or three weekly workouts appear to be equally effective for improving muscular fitness (Westcott, 2012). However, as individuals become more advanced and train at higher effort levels, more recovery time is needed between successive exercise sessions (Mclester et al., 2003). While appropriate recovery time is essential for both muscular strength and muscular endurance training, the use of lighter weight loads and more repetitions with endurance exercise emphasises the type I (slow twitch) muscle fibres. Type I fibres fatigue more slowly and recover more quickly than type II (fast-twitch) muscle fibres. Consequently, three weekly exercise sessions may be effective for muscle-endurance training in advanced individuals. If an equal or greater number of repetitions cannot be completed in subsequent workouts, the training frequency should be reduced to two weekly exercise sessions.

ii. *Intensity:* There is an inverse relationship between the amount of resistance used and the number of repetitions completed (Mclester et al., 2003). One objective of muscular endurance training is to work the targeted muscles to fatigue in the end range of the anaerobic energy system (Mclester et al., 2003). For most individuals, this requires an exercise set that continues for about 75 to 100 seconds. Given a training speed of six seconds per repetition, this is a range of 12 to 16 controlled repetitions. Generally, 12 repetitions can be completed with about 70% of maximum resistance, and 16 repetitions can be completed with about 60% of maximum resistance. It is therefore recommended that the training intensity for muscular endurance development be between 60 and 70% of maximum resistance (Mclester et al., 2003; Westcott, 2012).

iii. *Repetitions:* The recommended repetition range for enhancing muscular endurance is between 12 and 16 controlled repetitions that fatigue the targeted muscles within 75 to 100 seconds (Westcott, 2012). Rather than train outside the normal anaerobic energy system, the resistance should be increased by approximately 5% when 16 controlled repetitions can be completed. This weight load increase typically shortens the set by two to four repetitions and permits the application of the double-progressive training protocol (Westcott, 2012).

iv. *Sets:* Inherent in the development of muscular endurance is the repeated performance of the training bouts. Therefore, most programmes designed for increasing muscular endurance incorporate multiple sets of each training exercise. Another application of muscular endurance training is to take relatively brief rest periods between successive exercise sets. Unlike muscular-strength training, which emphasises full recovery between exercise sets, muscular-endurance training is typically characterised by rest periods of ≤30 seconds between exercise sets, or 30–60 seconds or less in higher-intensity circuits. It is therefore recommended that individuals training for muscular endurance perform two or three sets of each exercise with ≤60 seconds of rest between successive sets (Kaesler et al., 2007).

v. *Type:* There are many types of resistance that are effective for improving muscular endurance. While these include bands, medicine balls, and other forms of resistance, standard free-weight and machine exercises are well-suited for muscular endurance training because the weight loads can be progressed with consistency and in small increments. Although all of the major muscle groups should be included, it is not necessary to train each muscle group independently. For example, a workout that includes bench presses, shoulder presses, and bar dips may not require a specific triceps exercise, as the triceps are targeted in all of these multi-muscle exercises. In fact, exercise selection during the initial phase of load training can develop integrated strength and endurance by continuing to emphasise the five basic movement patterns (Kaesler et al., 2007).

2.8 Training Modalities to Improve Muscle Hypertrophy

Muscular hypertrophy is the increase in cross-sectional area caused by the magnitude and duration of muscle loading. Ideal resistance-training programmes for optimal muscle hypertrophy are an enormous topic with surprising little research to support them. However, a literature review of the mechanisms for hypertrophy and their application to resistance training does shed some light on this important area Schoenfeld et al. (2021) extensively reviewed the available research on muscle hypertrophy and resistance training and drew, among others, the following conclusions based on his findings:

There are a number of factors that determine the rate and extent of skeletal muscle hypertrophy achieved through resistance training. Non-training variables such as genetic background, age, and gender have been shown to govern the hypertrophic response to training protocols. Furthermore, it becomes progressively more difficult to increase lean mass as one gains training experience, which emphasises the importance of periodized cycles within an exercise program (Schoenfeld, 2020).

Apart from individual factors, available research suggests that maximal gains in muscle hypertrophy are achieved by training regimens that use a repetition range of six to 12 repetitions per set with rest intervals of 60 to 90 seconds between sets. Multiple-set training (rather than single-set routines) appears to produce superior hypertrophic results. Of the multiple sets, at least some should be performed to the point of muscular failure (Schoenfeld, 2020). Therefore, to allow for optimal gains in muscle tissue, resistance training should be periodized so that muscle growth culminates in a brief period of higher volume overreaching followed by a taper.

2.9 Adaptations to Resistance Training

There are 2 main long-term physiological adaptations to progressive resistance training: an increase in muscular strength and an increase in muscle size (hypertrophy). Early-phase increases in strength are primarily attributed to neural improvements (Aube et al., 2022; Schoenfeld et al., 2019; Worthey, 2016). This is known as motor learning. The repeated performance of a resistance exercise results in more efficient activation of the motor units that are involved in the exercise movement. Motor units that produce the desired movement will be facilitated, while the motor units that produce the opposing movement will be inhibited. All of this leads to stronger contractions of the prime mover muscles (Aube et al., 2022).

Muscle hypertrophy is an increase in the size of muscle tissue. Resistance training results in muscle hypertrophy mainly due to three primary mechanisms: mechanical tension, metabolic stress, and muscle damage (Schoenfeld et al., 2020; 2021). Changes in muscle size generally take a couple of months to become significant (DeFreitas, Beck, Stock, Dillon, & Kasishke, 2011). During a single bout of resistance training, muscle protein synthesis is suppressed and muscle protein breakdown is increased, so that the net protein balance is in a negative state. After completion of the workout, muscle protein synthesis is increased 2- to 5-fold along with nutrient delivery, with effects lasting 48 hours or more post-exercise (Hamarsland et al., 2017). Thus, when repeated bouts are performed over time and sufficient recovery is given between sessions, the synthetic response outpaces that of breakdown, resulting in an increased accretion of muscle proteins (muscle hypertrophy) (Hamarsland et al., 2017).

During the hypertrophic process, contractile elements enlarge and the extracellular matrix expands to support growth (Schoenfeld et al., 2010; 2021). Growth occurs by adding sarcomeres, increasing noncontractile elements and sarcoplasmic fluid, and bolstering satellite cell activity. Strength gains can also be the result of muscle hypertrophy. Depending on the intensity and volume of the training session, resistance training can cause varying degrees of muscle tissue microtrauma. The remodelling of muscle tissue that occurs in the days following a resistance training session in which you push yourself to near maximum results in the growth of muscle fibres as well as small increases in muscle strength (Schoenfeld, 2020). The satellite cells within the muscle are largely responsible for building larger and stronger muscle fibres (Snijders et al., 2015). The cross-sectional area of strength-trained muscle fibres increases as a result of two tissue adaptations (Tieland, Trouwborst, & Clark, 2018).

There is an increase in the number of myofibrils (contractile proteins) within the muscle fibre; this is referred to as myofibrillar hypertrophy and results in greater contraction force (Boonyarom & Inui, 2006). Progressive strength or resistance training also results in an increase in the muscle cell sarcoplasm that surrounds the myofibrils but is not directly involved in contractile processes. This is known as sarcoplasmic hypertrophy (Boonyarom & Inui, 2006). It does not result in greater muscle contraction force, but it does increase the cross-sectional area, or the size of the muscle. Many people experience what is commonly referred to as the "muscle pump" immediately following a resistance training workout. This form of hypertrophy is related to transient hypertrophy. It is caused by the accumulation of fluid in the spaces between cells due to muscle contraction, and it quickly diminishes post-exercise as the fluid balance between the various tissues and compartments returns to normal (Boonyarom & Inui, 2006; Cribb, Williams, Stathis, Carey, & Hayes, 2007; Tieland et al., 2018).

For most people, a standard resistance exercise programme will produce both myofibrillar and sarcoplasmic hypertrophy in the trained muscle fibres (Haun et al., 2019). Some research shows that resistance-training protocols that involve heavy weight loads, low repetitions, and long rests between sets will favour myofibrillar hypertrophy, whereas resistance-training protocols that involve moderate weight