The Effect of High-Intensity Circuit Training Versus Traditional Strength Training on Physiological and Psychological Responses in Healthy, Recreationally Active Women

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Abstract

Strength training (ST) is touted as a pillar for health improvement as well as chronic disease prevention and management. In addition to directly increasing muscle mass and strength, it also enhances movement control, improves functional abilities, increases bone mineral density, and reverses aging factors. Further, it is associated with reduced risk of developing numerous physical and mental health problems, including but not limited to cardiometabolic health complications, obesity, sarcopenia, depressive symptoms, and psychological distress. Despite the myriad of health benefits, participation rates for women have remained low, with only roughly 1 in 4 women regularly engaging in ST, and there is a dearth of research examining the impact of different training styles on women. Therefore, the aim of this thesis was to investigate women's perceptions of and barriers to ST as well as compare two popular training modalities amongst women. First, a survey was conducted with the purposes of determining if 1) ST preferences and practices differed between resistance trained versus recreationally trained women, and 2) perceived benefits and barriers to ST were different between resistance trained, non-resistance trained, and recreationally trained women. Over 2,700 responses were analyzed, and the main findings were: resistance trained women expressed greater preference for instruction and planning, greater perceived ability to perform exercises, and stronger routine compared to recreationally trained women; resistance trained women scored highest across all four perceived benefit factors (social, psychological, body image, and health) and lowest across all four perceived barrier factors (time-effort, physical, social, and specific); and time-effort was the highest reported barrier for both recreationally trained and non-resistance trained women. Following this, a short-term crossover study was conducted to compare acute physiological and psychological outcomes between high-intensity circuit training (HICT) and traditional strength training (TS) in resistance-trained women. A total of 26 women participated, and the main finding was that HICT had greater blood lactate, average and max heart rate, session rating of perceived exertion, and state anxiety compared to TS. Lastly, an 8-week longitudinal training study was implemented to investigate differences in strength and body composition as well as compare the psychological impact between HICT

and TS. Interestingly, both HICT and TS were equally effective in increasing strength and lean body mass and decreasing body fat in trained women when sets were terminated close to failure, but HICT was able to complete the same amount of work in less time and thus had higher training density. In terms of psychological impact, both groups led to improvements in perceived physical and mental health, with strong social environment cited as positively impacting overall enjoyment and adherence and emphasis on body functionality improving participants' body image struggles. Personal preference and time constraints were recommended as variables to consider when choosing training modality. Further research is needed to better understand perceptions of ST and the impacts of different training styles on women in order to improve adherence rates in the long run.

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List of commonly used abbreviations

1RM: 1-repetition maximum

3RM: 3-repetition maximum

ACSM: American College of Sports Medicine

ADL: activities of daily living

ANOVA: analysis of variance

BLA: blood lactate

BMD: bone mineral density

CI: confidence interval

CT: circuit training

DB: dumbbell

DXA: dual-energy x-ray absorptiometry

EPOC: excess post-exercise oxygen consumption

FM: fat mass

HICT: high-intensity circuit training

IRB: Institutional Review Board

HR: heart rate

LBM: lean body mass

NRT: non-resistance trained

NSCA: National Strength and Conditioning Association

QD: qualitative description

REC: recreationally trained

RPE: rating of perceived exertion

RT: resistance trained

sRPE: session rating of perceived exertion

STAI: State Trait Inventory

TS: traditional strength training

Attestation of authorship

“I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor used artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.”

Sohee Carpenter

Co-authored works

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We, the undersigned, hereby agree to the percentages of participation to the chapters identified above.

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Ethics approval

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Chapter 1 Introduction

Section 1: Background and rationale

Resistance training is a type of physical activity in which external resistance causes muscles to contract to increase strength, muscle, endurance, and more. Implements such as barbells and dumbbells (DBs), exercise machines, and body weight are commonly utilized forms of resistance [1].

Resistance training offers a multitude of physical and psychological health benefits. Some physical benefits include increased muscle mass [2], improved muscular strength and endurance [3], increased bone mineral density (BMD) [4], and prevention of metabolic syndrome [5]. Psychological benefits include improved self-esteem and confidence, reduced anxiety and depression symptoms, and increased quality of life [6, 7].

Circuit training (CT) and traditional strength training (TS) are two popular forms of resistance training. With CT, a sequence of exercises is performed back-to-back with little to no rest. While CT is typically performed with lower loads, high intensity CT (HICT) involves pushing sets closer to muscular failure. With TS, all sets of one exercise at completed with moderate to long rest periods before moving onto the next exercise.

Despite the plethora of health benefits associated with resistance training, the majority of women are not regularly resistance training. Specifically, a mere 25.8% of US women meet the National Strength and Conditioning Association (NSCA) recommendation of resistance training a minimum of two days per week [8, 9]. While non-resistance trainers seem to understand the benefits of resistance training [10], some of the biggest cited perceived barriers include time-effort (e.g. "[resistance training] is too inconvenient") [10, 11] and social (e.g. "my friends do not resistance train) [12].

Currently, women are underrepresented in sports science studies, with only 39% of participants in training studies being female [13]. Our understanding of women in resistance training is thus limited. To that end, more research is needed specifically on women to determine their current resistance training practices, preferences, and perceptions, as well as the physiological and psychological impact of different styles of training.

Section 2: Purpose of the research

The overall aim of this thesis was to answer the question, "What are the effects of high-intensity CT versus TS on physiological and psychological responses in trained women?" The specific research questions were:

1. What perceptions do women have about resistance training?
2. How do these different training styles affect women's physiology?
3. How do these different training styles affect women's psychology?

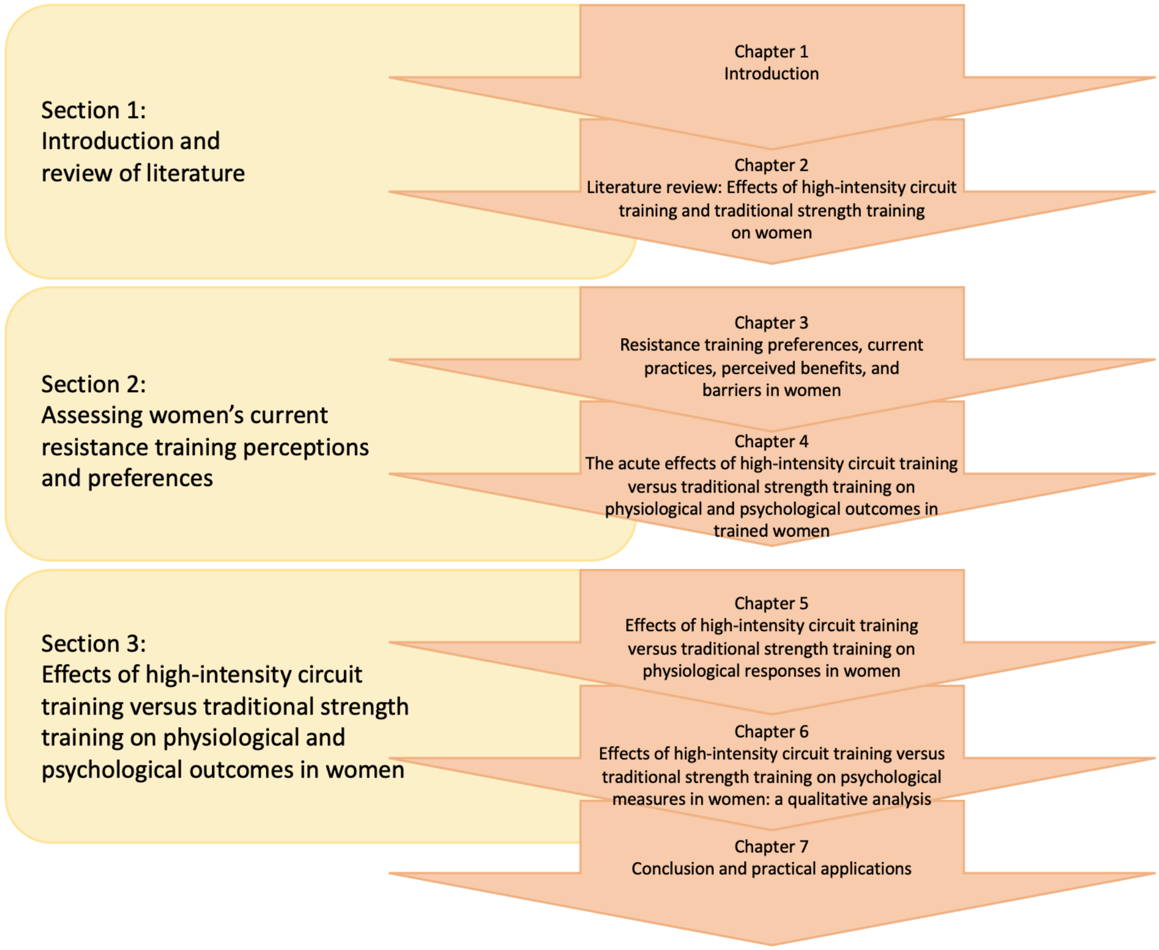
Section 3: Significance of the thesis

Despite the plethora of resistance training benefits, participation rates amongst women remain low [8]. The addition of regular resistance training into women's exercise regimen can augment health outcomes such as strength and muscle[14], quality of life [15], and activities of daily living (ADL) [16], thus encouraging more women to regularly lift weights is important. Insight into women's current resistance training practices and perceived benefits and barriers to resistance training will allow for better targeted interventions to address said benefits and barriers. Additionally, not enough is known to date about the impacts of different styles of resistance training on women. There is, in particular, a dearth of research on HICT and also none directly comparing HICT to TS in women. Finally, an in-depth qualitative survey exploring women's experiences with HICT and TS will provide further insight into the two training modalities. Taken together, the findings of the subsequent chapters will increase the breadth of knowledge about resistance training in women and ultimately inform constructive recommendations for gyms and practitioners to better help women.

Section 4: Structure of the thesis

This thesis is presented in the pathway two format, in which each chapter is presented in journal article format. See Figure 1-1. The first section introduces the thesis (Chapter 1) and provides an overview of the literature to date on the effects of HICT and TS in women (Chapter 2). The second section covers resistance training preferences, current practices, perceived benefits, and barriers in women (Chapter 3) and also examines the acute effects of HICT versus TS on physiological and psychological outcomes in trained women (Chapter 4). The third and final section investigates the effects HICT versus TS on physiological (Chapter 5) and psychological (Chapter 6) measures in women, and wraps up with a conclusion, practical applications, and directions for future research.

Figure 1-1 Structure of thesis



Chapter 2 Literature Review

Section 1: Introduction

Resistance training is touted as a pillar for health improvement as well as chronic disease prevention and management [17, 18]. It is associated with reduced risk of developing physical and mental health problems, including, but not limited to, cardiometabolic health complications [19, 20], obesity [21], sarcopenia [22], and chronic diseases such as hypertension [23], depressive symptoms [24], as well as psychological distress [25]. Additionally, resistance training directly increases muscle mass [14] and strength [26], enhances movement control [27], improves functional abilities [28, 29], increases BMD [30-32], reverses aging factors [33, 34], and more.

The NSCA recommends adults resistance train a minimum of two days per week [9]. Similarly, the American College of Sports Medicine (ACSM) recommends resistance training two or three days per week [35]. While participation rates amongst adults in the United States have increased in recent decades from 1997 to 2018 (19.8% and below 30%, respectively) [36, 37], overall participation remains low.

Adherence is operationally defined as at least six months of physical activity participation, and long-term adherence is defined as at least one year of regular participation [38]. Women are less likely to be adherent to resistance training recommendations compared to men, with roughly 1 in 4 women regularly resistance training [8]. Specifically, women are 34% less likely to meet muscle strengthening recommendations compared to men, which highlights the importance of continued research in this population to better understand and address the lower participation rates.

As adherence is lower in women, it's important to understand the factors that contribute to exercise behavior. Ultimately, we want to better inform messaging and promotion to increase adherence and participation amongst women who lift weights. The aim of this review is therefore to explore the existing evidence on resistance training benefits and barriers as well as psychological and physiological impacts of resistance training in women.

Section 2: Resistance training adherence variables

There are several variables that impact resistance training adherence. One crucial factor is enjoyment, as it makes individuals more likely to continue the activity [39]. Specifically, giving women the option to choose their exercise modality – or in the case of resistance training, the specific style of resistance training they wish to perform – rather than promoting a style they do not like can have a positive influence on enjoyment which will then make it more likely they will continue the activity [40]. Women who enjoy the exercise also enjoy its impact on their quality of life, which further motivates them to continue exercising, thus creating a positive feedback loop [38].

Another important element of physical activity adherence is social support. In particular, the camaraderie and bonding experience of setting and reaching goals together may increase consistency [41]. This support can come from friends, siblings, parents, or partners, and can also include verbal encouragement from others such as instructors and medical professionals. It should be noted that social support may be a more important factor in the initiation of exercise activity rather than its maintenance in women [39]. Interestingly, those who are more adherent to exercise are also more likely to actively seek out social support to help with their consistency as they recognize its importance. How a woman feels about her ability to engage in exercise over the long term can also affect the role that social support plays in her adherence [42].

Finally, self-efficacy is one of the most important correlates of exercise behavior in women. Self-efficacy refers to situation-specific self-confidence – in other words, the confidence an individual has that they can participate in a behavior successfully [43, 44]. Those with higher self-efficacy at the beginning of an exercise program are more likely to maintain their adherence over six months [45]. Self-efficacy increases concurrently with continued adherence [46], and also reliably predicts long-term exercise behavior [47-49]. Thus, strategies to improve self-efficacy for different resistance training modalities should be investigated.

Section 3: Perceptions of and barriers to resistance training in women

Women's perceived barriers to resistance training can be categorized into six different themes: social, psychological, physical, gym infrastructure and financial, time effort, and family commitments and other obligations [50]. Social barriers refer to gender-based and social stigma, such as women being perceived as 'cardio bunnies' and feeling unwelcome in the weights section of the gym with men 'taking up space' [51]. Some women also mention receiving unwanted attention from men, including unsolicited advice or even verbal discouragement, and at times having workouts disrupted by men who move equipment women were using to take for themselves [51, 52]. Further, women report family members, peers, and significant others are oftentimes unsupportive and actively discourage resistance training, telling them they need to lose weight rather than "bulk up" [53] or saying that female bodybuilders look "sick and repulsive" [52].

Psychological barriers include feeling demotivated when visual progress does not occur right away or if weight stagnates or increases, even if weight change is due to increased muscle mass [54]. Additionally, not all women particularly enjoy resistance training or find the experience uncomfortable [54, 55]. Others, particularly older women, feel they do not know what to do in the gym (e.g. performing particular exercises or using the equipment) [56], which makes them more likely to turn to aerobic exercise [54]. Some women also express they do not believe that resistance training is as important for women as it is for men [57] or mistakenly think that resistance training makes women “big and muscly and fat” [52].

Concern about injury and pain from resistance training are examples of physical barriers. Older women worry about their ability to lift weights [58], and other women believe that resistance training would not ‘hurt as much’ if they were fitter [55].

Poor accessibility and inclusivity of many gyms are cited as common gym infrastructure barriers [55], as is the unavailability of resistance training equipment in communities [52]. Lack of instructors and appropriate supervision reduces accountability, making it easier for women to discontinue resistance training [59]. Older people also emphasize the importance of a good trainer to oversee their form and help ensure they are not injured while training [53]. Another related barrier is financial constraints, such as having to purchase gym equipment or a gym membership they might not be able to afford [58].

Lack of time is cited as another barrier to starting and maintaining resistance training, particularly when trying to juggle exercise with work responsibilities [60]. While having a consistent schedule facilitates resistance training on a regular basis, holidays or loss of routine makes it tough to continue [53]. As well, women who work are oftentimes exhausted and have to come home to ‘cook and do the dishes’, which gets in the way of making time to train [59].

Finally, family commitments and other obligations are reasons for low engagement in resistance training. Women mention multiple life stressors and obligations that make fitting in resistance training seem overwhelming and unrealistic [53, 56]. For example, a woman who is working a full-time job while also being the primary caretaker with one or more children at home may find herself with limited time and energy to devote to dedicated exercise. This oftentimes means women skip lifting weights to prioritize other commitments.

On the flipside, women's motivators for resistance training can be divided into four themes: social, psychological, knowledge, and gym infrastructure and financial. The social aspect of resistance training provides women with support and encouragement to continue to show up and push themselves, especially for older women and those with health conditions [58]. Some women note they benefit from group discussions, and older women emphasize that training around younger women is motivating [61]. Women also find that family, friends, and healthcare professionals can be particularly encouraging, such as when people around them are lifting and they want to join in to 'follow the trend' [55] or they hear other women's success stories [56].

Psychological motivators include improved body image and feeling excited by changes in their physique [57]. Resistance training gives some women confidence and makes them feel empowered [62], and other measures of progress such as strength gains, increased bone density, and improved ADL are particularly encouraging [59]. Resistance training also makes women feel happier, more energetic, and invigorated [58, 61], and some enjoy the physical challenge [62].

Increased knowledge of resistance training and its benefits encourage some women to begin and continue resistance training [54]. For younger women, changing their parents' perception of lifting weights is oftentimes pivotal in enabling resistance training access [58]. Older women feel that resistance training improves symptoms of health conditions they are experiencing and delays disease progression [58].

The last motivator theme is gym infrastructure and financial. Having a qualified, supportive instructor provides women with guidance and increases the likelihood they will show up to train [60]. Some also express that knowing that their coaches believe they can perform a particular exercise makes them feel less nervous to try [58]. Ease of gym access [61] and cash incentives (i.e. for participating in a training study) also motivate women to lift weights [59].

Understanding these barriers and motivators for resistance training will help practitioners better target interventions and improve recommendations to reduce obstacles and provide working solutions for women. Ultimately, this information can help increase women's long-term resistance training adherence rates.

Section 4: Adaptations to HICT

CT, developed in 1953 by Morgan and Anderson, refers to a style of training in which a series of exercises are performed in sequence whereby one exercise is performed after the next with little to no break [63, 64]. Participants typically perform between 8 to 20 repetitions utilizing any combination of body weight, elastic resistance, free weights (e.g. DBs and barbells), and exercise machines. The fast-paced nature of CT leads to a shorter workout session compared to training methods that include longer rest periods. In addition to less time spent exercising, other benefits of CT are its impact on cardiorespiratory function, body composition, bone metabolism, cardiometabolic risk factors, and motivation to exercise [65-71]. Specifically, CT improves resting and exercising blood pressure and may positively impact metabolic variables (cholesterol and glucose) [72]. It also improves VO_2 max, aerobic performance, and maximum aerobic speed [73]. CT has a similar or even higher metabolic cost compared to a combination of general aerobic and resistance training [64, 74].

In contrast to standard CT, HICT involves training with higher loads with higher perceived exertion closer to muscular failure. One of the drawbacks of CT is that due to the lower training loads and thus decreased stimulus, it is less effective at improving BMD and 1-repetition maximum (1RM) strength compared to training at higher intensity [75-77]. Unlike CT, HICT produces the same muscular force output as in a traditional heavy strength training session [78, 79] with the primary advantages of having higher cardiovascular demands and being more time-efficient [78].

Adaptations in men

When it comes to resistance training research, there are currently more published studies in men than there are in women [13, 80]. Further, the totality of research on HICT specifically – in either sex - is somewhat limited, making it necessary to review what is observed in men undertaking HICT. In healthy, middle-aged untrained men, 12 weeks of HICT led to higher reductions in fat mass and blood pressure and greater improvement of blood lipids (total cholesterol, low density lipoprotein-cholesterol, and triglycerides) compared to CT [81]. The higher intensity nature of HICT could increase excess post-exercise oxygen consumption, which may modestly increase resting energy expenditure and reduce respiratory ratio [82]. Additionally, healthy, sedentary men experience significant improvements in physiological health markers such as resting heart rate (HR), lean muscle tissue, and insulin levels from HICT [83].

Interestingly, HICT promotes cardiovascular adaptations as well as other fitness adaptations in men [78, 83]. When compared to TS, men performing HICT completed similar work despite alternating exercises during the rest period. Participants maintained a significantly higher average HR at roughly 71% of maximum [78], falling within the 60-90% range suggested by the ACSM for the development of cardiorespiratory fitness [26]. Further, men in an 8-week training intervention decreased body fat following HICT significantly more than following TS and similarly increased lean body mass (LBM) and 1RM strength [79].

Physiological adaptations in women

Like the research in men, there are a mere handful of studies on the physiological impact of HICT on women. In terms of body composition, HICT reduces body fat [84, 85] and increases LBM while also lowering waist-to-hip ratio and body mass index [85, 86]. Improvements in insulin sensitivity are also observed [87]. Additionally, a 4-week HICT intervention in female college students led to significant increases in handgrip strength, 1-minute sit-up test, and a 1,200-meter running test [84]. This is especially interesting given this study only included body weight exercises, highlighting that HICT does not require external loads (e.g. DBs, barbells) to induce fitness benefits.

In elderly women, a 12-week intervention yielded significant improvements in isokinetic strength, lean mass, and BMD following both HICT and TS, though only HICT experienced a significant decrease in fat mass and improvement in cardiovascular fitness and walking economy [88]. The differences in outcomes between HICT and CT have led researchers to conclude that the higher loading of HICT is key to stimulating BMD increases. Indeed, compared to moderate intensity CT, only HICT was sufficient to stimulate osteogenesis at the spine, though both training modalities produced similar muscle mass increases [89].

Psychological adaptations in women

Research on the impact of HICT on psychological measures in women is scant. Perception of quality of life improved after a HICT intervention in young women [86], though in a different study, there was no perceived improvement in elderly women [66]. It is possible that this discrepancy is due to the use of different questionnaires to assess perceived quality of life (health-related quality of life questionnaire, German version [90], and the quality of life in the elderly questionnaire, Spanish version [91]), thus we cannot rule out the likelihood of the participants in the latter study reporting quality of life improvement had they taken the health-related quality of life questionnaire.

As the research in this area is sparse, more studies are needed to draw firmer conclusions and better understand how HICT impacts women psychologically. Namely, we currently do not understand the effect of HICT on outcome variables such as mood, anxiety, body image, self-efficacy, and more.

Section 5: Adaptations to TS

TS is another form of resistance training that is extremely popular amongst active adults. TS primarily utilizes higher loads, lower repetitions, and longer inter-set rest periods compared to CT. Loads typically are 65-90% of the 1RM [92], and all sets of each exercise are typically performed one at a time before moving onto the next exercise.

Adaptations in men

In men, TS increases maximal strength [93, 94], muscle mass [79, 95], work economy [96], and BMD [97]. However, compared to CT, TS offers a lower cardiovascular and metabolic stimulus as measured by metrics such as HR, VO_2 max, blood lactate (BLA), and post-exercise oxygen consumption [78, 98], and lesser reductions in body fat [79]. Thus, the drawbacks of TS include the time required to complete a workout session, moderate cardiovascular health benefits compared to other forms of training (e.g. CT, aerobic training), and that it may not lead to as much body fat loss [79].

Physiological adaptations in women

There are many similarities and some differences in physiological adaptations between men and women. In healthy women between the ages of 25 and 35, TS leads to positive changes in motor, musculoskeletal, and cardiorespiratory fitness [99, 100]. Specifically, TS can improve strength and muscle endurance as well as muscle thickness and cross-sectional area [101].

Interestingly, compared to men, women experienced significantly less acute strength loss immediately after a resistance training bout (26.8% and 15.5%, respectively), though strength loss levels were comparable at the 72-hour post-workout timepoint [102]. This strength loss is believed to be due to peripheral and central neuromuscular fatigue, with women believed to be more resistant to neural and metabolic fatigue [103]. Women also had similar recovery and indications of exercise-induced muscle damage, as their arm circumference and muscle thickness increases were similar to that of men at the 72-

hour mark. Overall, despite differences in acute fatigue responses, there appear to be no significant differences in exercise-induced muscle damage between men and women [102, 104].

TS can also lead to decreases in body fat in women [105]. Specifically, following a 12-week resistance training intervention, women decreased total and regional fat deposition, with the biggest reductions seen in the android region [106]. Women implementing TS often experience body recomposition [107], gaining muscle mass and losing body fat at the same time [108-110]. Additionally, over a two-year study period, premenopausal women who were resistance training had attenuated increases in intraabdominal fat compared to the control group [111]. The proposed mechanism of these body composition improvements include increased resting metabolic rate, improved insulin sensitivity, and enhanced sympathetic activity [112].

There are other physiological adaptations to TS in women. TS increases resting metabolism by two main pathways. First, the tissue microtrauma that occurs from TS requires large amounts of energy for muscle remodeling processes for up to 72 hours post-training [2, 113, 114]. And second, the increased muscle mass from TS requires roughly three times more energy at rest for tissue maintenance compared to fat [115]. Insulin sensitivity can also improve and 24-hour fasting blood glucose can lower in those with impaired fasting glucose following TS, particularly using loads up to 85% 1RM. Further, TS lowers resting blood pressure in women with metabolic syndrome [116, 117], improves blood profiles (specifically total cholesterol, triglycerides, and high-density lipoprotein) [118, 119], and may improve vascular condition [120, 121]. TS also increases BMD in premenopausal women [122, 123], specifically in the lumbar spine [124].

In older women, the rate of BMD loss increases progressively with age: 5% loss annually in the first few years following menopause, then 2 to 3% per year after [125]. This is a concern as reduced integrity of bone tissue can lead to osteoporosis, which impacts 30% of all postmenopausal women in Europe and in the United States [126]. Further, of these women, 40% will experience at least one osteoporotic fracture during their lifetime. Resistance training can prevent bone mineralization in older women [127, 128] and even increase BMD compared to those not regularly resistance training [129-132]. Specifically, training at high loads of 70% of 1RM or greater may be needed to optimally enhance BMD [129].

In addition to decreased BMD, age-related muscle mass loss (i.e., sarcopenia) is also a concern in older women. With rates of muscle mass loss between 3 to 8% each decade after age 30 [133] and 5 to 10% each decade after age 50 [134], multiple health outcomes are negatively impacted, some of which include increased risk of obesity, dyslipidemia, type 2 diabetes, and cardiovascular disease [135] as well as glucose intolerance and associated health issues [135, 136]. A growing body of evidence indicates that resistance training may be the most promising method for increasing muscle mass and strength in aging women [22]. In postmenopausal hypertensive women, a higher per-set perceived exertion led to greater post-exercise hypotension and increase in forearm blood flow in addition to greater increase in sympathetic and greater decrease in parasympathetic modulations of the heart [137]. Other physiological adaptations include a reversal in aging factors [33], increased power [138], improved insulin sensitivity [139], and more. Thus, TS has a plethora of positive physiological impacts on both pre- and post-menopausal women.

Psychological adaptations in women

There is some research on the psychological impact of TS in women. Acutely, women who trained at both higher and lower perceived exertion of resistance training in one study did not increase measures of negative affect [140]. This is important as minimizing displeasure and negative feelings is considered a crucial aspect of behavior compliance [140]. Additionally, another study found that training at 70% 10-repetition maximum (10RM) increased enjoyment and decreased state anxiety, while training at 100% 10RM had the opposite impact (less enjoyment and increased state anxiety) [141]. This suggests that the associated increases in fatigue and tension of training at too high of a load or proximity to failure may negatively impact people's experience. In still another study, TS increased measures of positive well-being with no change in psychological distress, with those with lower initial quality of life scores experiencing a higher increase in positive well-being [142].

Long term, TS can reliably improve symptoms of anxiety, particularly after moderate load training (50-60% 1RM) compared to higher load training (80% 1RM) [143]. TS also increases self-efficacy scores [144], reduces depression symptoms [145, 146], improves cognitive function in healthy older adults, reduces symptoms of dementia in those with cognitive impairments [147], and improves memory [148-150]. Another study concluded that women learned to reframe and view their body in a more positive light as a result of TS. They became more focused on becoming bigger or stronger rather than obsessing over weight and becoming smaller, developing a functional focus of the body, and feeling satisfaction and peace from knowing that the adaptations were the best for their body [151]. Participants additionally explained that TS helped free up mental capacity to focus on other areas of their life as they worried less about what others thought of them, and they also prioritized self-care more and increased their confidence [151].

A recent qualitative study found that gym-based TS was perceived to increase well-being, divided into five themes: self-acceptance, personal growth, flow state, social affiliation, and autonomy [152]. Specifically, participants reported an increase in self-esteem and confidence from resistance training, which then further motivated and empowered them to adhere to their training goals. The continual improvement in the gym was also cited as a motivating factor for personal growth, and the intensity of their workouts in particular was highlighted as an important component of an enjoyable experience. TS also put them in a state of flow – the psychological state of being cognitively and emotionally absorbed in an activity [153] – and provided a mental escape, allowing them to "dissociate from the outside world." The social connectedness of resistance training was also mentioned as a source of motivation, as being around friends engaging in the same activity for support and encouragement was helpful in achieving their training goals. Finally, TS helped participants resist external pressures and live by their own standards rather than trying to keep up with others' expectations.

Studies comparing HICT and TS

To date, there are four published studies directly comparing HICT and TS in men. Alcaraz and colleagues found that trained men performing HICT completed non-significantly different volume loads and experienced greater cardiovascular load compared to TS during an acute resistance training bout [78]. The researchers thus concluded that HICT is useful for stimulating cardiovascular and endurance adaptations. A follow-up 8-week longitudinal training study found that HICT elicited strength and muscle mass improvements and increases in muscular power similar to those of TS, and HICT produced significant decreases in body fat percentage [79]. In an elderly population, a 12-week study similarly concluded that HICT is as effective as TS in terms of improving muscle mass, strength, and BMD, and is more effective at stimulating cardiovascular adaptations and decreasing fat mass [88]. Most recently, greater cardiorespiratory and metabolic responses as measured by oxygen consumption, HR, BLA, and excess post-exercise oxygen consumption (EPOC) was observed in soccer players following an acute bout of HICT compared to TS, despite similar loads lifted between groups [98].

Unfortunately, there are currently no published studies comparing HICT and TS in women. Thus, while there are a myriad of observed physiological and psychological benefits of TS in women, and HICT appears to result in many of the same physiological benefits as TS and more among men, further research is needed to gain an understanding of the acute and chronic physiological and psychological differences between the two training modalities in women.

Section 6: Conclusion

Resistance training adherence rates are lower amongst women compared to men. Multiple factors, including enjoyment, social support, and self-efficacy impact exercise participation. Women cite numerous barriers to resistance training including social (e.g. feeling unwelcome in the weights section of the gym, family and friends actively discouraging them from lifting), psychological (e.g. not knowing what to do with weights), time-effort (e.g. juggling competing responsibilities that leave them busy and exhausted), and more.

One way to potentially increase adherence and participation is to promote more styles of resistance training which leverage potential factors that can enhance adherence, such as time saving and social support. CT is often done in groups, increasing the potential for social support, and is more time efficient than TS. Unfortunately, CT may not produce all the same beneficial physiological effects, such as increasing strength, BMD, and lean mass, as TS. However, HICT is a variant of CT in which higher loads and closer proximity to failure is implemented, and the existing (albeit limited) data indicate it produces similar BMD, strength, and lean mass adaptations as TS.

While there is some research on the impacts of TS on women, there is very little on HICT, and none directly comparing HICT versus TS. Thus, further research is needed to explore these differences to better understand how resistance training affects women and to inform practical recommendations that may help improve adherence rates.

Chapter 3 Resistance training preferences, current practices, and perceived benefits and barriers in women

Prelude

The review of literature (Chapter 2) examined the existing evidence on resistance training benefits and barriers as well as physiological and psychological impacts of HICT and TS on women. HICT offers similar BMD, strength, and lean mass adaptations as TS with the added benefits of saving time and having higher cardiovascular demands. Unfortunately, there is a dearth of research on HICT specifically as well as zero studies to date directly comparing HICT and TS in women. Thus, the next step was to better understand women's current resistance training preferences, practices, and perceived benefits and barriers.

Section 1: Introduction

Resistance training is a form of physical activity that utilizes external resistance to strengthen the body. Common modes of external resistance include free weights such as DBs and barbells, exercise machines, resistance bands, and even body weight. There are many health benefits caused by resistance training, including improved muscular strength and endurance [3], increased BMD, reduced osteoarthritis, osteoporosis, and osteopenia risk [4], prevention of metabolic syndrome [113], fewer cardiovascular events, better glucose metabolism and insulin sensitivity, reduced all-cause mortality, and more [6]. Additionally, resistance training leads to significant improvements in cognitive abilities [148], reduces anxiety and depression symptoms, reduces pain intensity in those with low back pain, osteoarthritis, and fibromyalgia, improves sleep quality in depressed older adults, and improves self-esteem [7].

The NSCA recommends that adults resistance train a minimum of two days per week [9]. A recent report found an upward trend in adherence to muscle-strengthening activity guidelines from 1997 to 2018 in all age groups, yet participation rates remained low at 27.2% [36]. Another report found that 25.8% of US women resistance trained a minimum of twice a week compared to 34.8% of men [8].

Women report several barriers to participating in resistance training. College- and middle-aged women reported in a survey that most preferred a structured resistance training class due to increased instruction, exercise dedication, control, and social opportunities; and least preferred exercising completely alone [154]. Not having access to such structured classes could pose an obstacle to women's regular participation in resistance training. Further, a recent meta-analysis found that the most frequently reported barriers for women included gender-based stigmas, discouragement, and negative comments as well as boredom, poor knowledge of resistance training, and limited gym accessibility [50].

Other research noted time-effort barriers to be most prevalent [10], while still other research found that the cultural ideal of feminine bodies and the fact that weight lifting is widely regarded as a masculine activity deterred many women from lifting [155, 156]. Specifically, the lower participation in lifting by women has been described as a self-perpetuating cycle: women avoid the weights section of gyms due to their perception of the space as masculine; the dearth of women in these spaces reaffirms this perception and further perpetuates their avoidance of weights. Indeed, more recent research consisting of in-depth qualitative interviews with female gym staff and gym users revealed that they felt the following: 1) the weights section of gyms tended to be unwelcome for women as they were in ‘male territory’ (insufficient equipment provided for women’s needs, lack of consideration for women’s experiences, such as barbell collars being stored too high for many women to reach); 2) gym messaging and layouts were unwelcoming or insulting to women (e.g. a sign in the weights area reading: “If you are too weak to return your weights, please contact the fitness staff and the girls will be happy to assist you”); 3) the weights section was filled with aggressive ‘masculine performances’ and associated intimidation and harassment; and 4) many gym spaces made people feel like they are always ‘on’ and thus subject to scrutiny and judgment [157]. These barriers may be mitigated at least in part by encouraging more resistance training programs to be spearheaded by female trainers (or gyms hiring more female trainers) as women tend to be more inspired by same-gender role models [158].

More research is needed to better understand women’s current resistance training practices as well as their perceptions of training. With a better grasp of the preferences and practices of women participating in resistance training, better informed public messages, campaigns, and corporate efforts to increase women's participation may be possible. Thus, the aims of this study were two-fold: 1) to determine if training preferences and practices were different between resistance trained versus recreationally trained women, and 2) to determine if perceived benefits and barriers to resistance training were different between resistance trained (RT), non-resistance trained (NRT), and recreationally trained women (REC). We hypothesized that: 1) those engaging in regular resistance training would express greater preference for lifting compared to recreationally trained women, 2) those engaging in regular resistance training would report significantly different resistance training practices (completing more weekly sessions as well as more exercises and number of sets per session) compared to those only recreationally training, and 3) resistance trained women would perceive the benefits to be greater and barriers to be less than both non-resistance trained and recreationally trained women.

Section 2: Methods

Experimental approach to the problem

To ascertain resistance training preferences, practices, and perceived benefits and barriers amongst women, an anonymous online survey was administered. Participants were recruited from the authors' professional pages on various social media platforms (Instagram, Facebook, Twitter) and via a snowball recruitment strategy in which existing participants were asked to recruit additional subjects from their acquaintances.

Subjects

A total of 4,421 women accessed the anonymous online survey, and once partial responses were removed, 2,741 responses remained and were analyzed. Inclusion criteria were English-speaking women between the ages of 18 and 60. Participants were placed into one of three groups according to survey results. Those who reported no resistance training were placed in the NRT group; those who did participate in and sufficiently met the NSCA guidelines of resistance training a minimum of two sessions per week in the

RT group; and those who reported resistance training but did not sufficiently meet NSCA guidelines were placed into a third group, REC.

Participants were informed of the benefits and risks of the investigation prior to beginning the survey, which at the start explained that by participating in the survey they were providing informed consent, and that they were able to exit the survey at any point. The research was approved by Auckland University of Technology Ethics Committee on 12 August 2021, Reference number 21/291.

Procedures

Participants completed a self-reported survey consisting of 98 total questions divided into four main sections: 1) general information/demographics, 2) current resistance training practices, 3) resistance training preferences, and 4) perceived benefits and barriers. General information included questions about age, highest education level, marital status, income, country of residence, height, weight, current and past participation in sport, and injury status from resistance training.

Exercise Participation. Participants were asked to indicate if they participated in resistance training (using free weights, machines, or both, to increase muscular strength and conditioning). Those who responded yes were further asked to indicate the modality, frequency, average number of exercises per day, sets per exercise, repetitions per set, degree of effort (estimated repetitions in reserve) per set, rest intervals taken between sets, and average load per set.

Resistance Training Preferences. Participants were asked about their resistance training preferences using an adapted version of section two of the Exercise Preference Questionnaire – Brazil ($EPQ_{(stroke)}$ – Brazil) [159]. The original EPQ-Brazil consists of 33 total questions, with the second section consisting of 22 items assessing participants' opinions on seven factors: 1) presence of instructions/planning, 2) ability to perform physical exercises, 3) exercise with family/friends – program flexibility, 4) exercises in fitness centers with people of similar age, 5) exercise alone, 6) exercise in fitness centers with people with stroke, and 7) routine (planned, instructed, gentle, at home, morning exercises). Responses were recorded via a 5-point Likert scale ranging from 1) strongly disagree to 5) strongly agree. Test-retest reliability of the $EPQ_{(stroke)}$ was assessed via intra-class correlation coefficient, which was between 0.35 and 0.93 for the second section and overall was deemed acceptable [159]. While all questions were modified to be specific to resistance training (e.g. "I like my resistance training sessions to be planned"), items related to factor six (exercise in fitness centers - people with stroke) were omitted as they were not relevant to our research question. Given these relatively minor changes, we expected similar reliability to other versions as stated previously.

The Benefits and Barriers to Exercise. Participants were asked about their perceived benefits of and perceived barriers to resistance training using a modified version of the Benefits and Barriers to Exercise (BBE) Questionnaire [11], a 48-item survey presented via a 5-point Likert scale ranging from 1) strongly disagree to 5) strongly agree. For the benefits, 4 different subscales were calculated for each category (social, psychological, body image, and health), and for the barriers, 4 different subscales were also calculated for each category (time-effort, social, physical effects, and specific obstacles). Test-retest reliability of the total benefit score was 0.88, while the total barrier score was 0.68. Test-retest reliabilities of individual benefit and barrier subscale scores ranged from 0.60 to 0.86. The modified version used in this study included all 24 benefit and 24 barrier items originally utilized by Myers and Roth but were modified to specifically address resistance training issues only. The social factor included items such as "it [resistance training] builds companionship"; the psychological factor included items such as "it gives me confidence in myself"; the body image factor included items such as "it improves my self-image"; the health factor included items such as "it improves my strength". An example of a time-effort barrier was "it is too inconvenient" and "I am too lazy"; the physical barrier included items such as "I am too uncoordinated" and "I get too fatigued"; the social barrier included items such as "my family does not encourage it" and "my friends do not resistance train"; and specific barriers included items not covered in the other three domains, e.g. “it interferes with school” and “there are no convenient places for me to resistance train”.

Statistical analysis

Mean and standard deviations were calculated for resistance training experience, training practices, and training volume. Frequencies of responses were calculated for demographics, and categorical and ordinal data were reported as both absolute numbers and percentage of responses.

To analyze aim 1, a Chi-square test of independence was conducted to determine whether the outcome variables differed between the RT and REC groups. This was repeated for each categorical outcome variable. An independent samples t-test was conducted to analyze questions with quantitative dependent variables. To analyze aim 2, a one-way analysis of variance (ANOVA) was used to examine the difference in subscale Likert scores for benefits and barriers between groups. Descriptive statistics (e.g. mean, standard deviation) were used to present resistance training practices. For both aims, the magnitude of the difference between groups was presented as Cohen’s *d* effect sizes and interpreted using the following thresholds 0.2 = small, 0.5 = medium 0.8 = large. All analyses were completed using JASP (v 0.17.2.1, University of Amsterdam, Amsterdam, The Netherlands), and statistical significance was accepted at $p<0.05$.

Section 3: Results

Participant demographics are presented in Table 3-1. Most participants were between 25 and 34 years of age (n = 1,479, 54.0%) and residing in the United States of America (n = 1,394, 50.8%) with a bachelor’s degree (n = 1,282, 46.8%). Respondents were primarily around (n = 1,104, 40.3%) or above (n = 1,018, 37.1%) median household income, single (n = 1,092, 39.8%) or married (n = 1,116, 40.7%), with no children (n = 1,945, 71.0%). The average reported height was 164.68 ± 7.13 cm and average reported body mass was 70.50 ± 15.40 kg with a body mass index of 25.98 ± 5.34. Full participant demographics are presented in Table 3-1.

Table 3-1 Frequencies of demographic variables

Demographic Variable	Frequency *n* (%)
Age	
18-24	345 (12.6)
25-34	1479 (54.0)
35-44	664 (24.2)
45-54	204 (7.4)
55-60	49 (1.8)
Country of Residence	
Australia	65 (2.4)
Canada	237 (8.6)
Mexico	16 (0.6)
New Zealand	56 (2.0)
United Kingdom	531 (19.4)
United States of America	1392 (50.8)
Other	444 (16.2)
Education	
Less than a high school diploma	14 (0.5)
High school degree or equivalent	425 (15.5)
Bachelor’s degree (e.g. BA, BS)	1282 (46.8)
Master’s degree (e.g. MA, MS)	725 (26.5)
Doctorate (e.g. PhD, EdD)	158 (5.8)
Other	137 (5.0)
Household Income	
Below median household income	403 (14.7)
Around median household income	1104 (40.3)
Above median household income	1018 (37.1)
Not sure	216 (7.9)
Marital status	
Single (never married)	1092 (39.8)
In a domestic partnership	422 (15.4)
Married	1116 (40.7)
Divorced	103 (3.8)
Widowed	8 (0.3)
Number of Children	
0	1945 (71.0)
1	277 (10.1)
2	362 (13.3)
3	101 (3.7)
4 or more	42 (1.5)
Prefer not to answer	14 (0.5)

Training Practices

Of the participants sampled in the study, *n* = 1,972 (71.95%) met the threshold for the suggested amount of resistance training exercise for general health set forth by the NSCA and were placed in the RT group; *n* = 419 (15.29%) reported no resistance training and were placed in the NRT group; and *n* = 350 (12.77%) reported that they resistance train but did not reach the threshold to satisfy the NSCA guidelines and were placed into a third group, REC.

Training practices were evaluated using the Chi-square test of independence. Of those who reported some level of resistance training (RT or REC), *n* = 346 (14.93%) reported 1 year or less, *n* = 1,134 (48.92%) reported between 2 and 5 years, *n* = 404 (17.42%) reported between 6 and 9 years, and *n* = 437 (18.82%) reported 10 or more years of resistance training experience. A total of *n* = 975 (41.99%) reported spending an average of 3-4 hours per week resistance training. The vast majority (*n* = 1,985, 85.49%) reported using primarily free weights (e.g. DBs, barbells) as their lifting equipment of choice, with each lifting session lasting between 30 and 59 minutes (*n* = 1,362, 58.66%), including between 5 and 8 exercises (*n* = 1,720, 74.07%) and 2-3 working sets per exercise (*n* = 172, 74.07%), terminating each set at 2 repetitions short of failure (*n* = 842, 36.26%), with between 30 seconds and 1 minute 59 seconds of rest between sets (*n* = 1,796, 77.34%). Participants largely categorized their lifting style as bodybuilding (*n* = 1,113, 47.93%), and the majority reported that they were following a structured, planned lifting program (*n* = 1,275, 54.91%).

There was a statistically significant difference between RT and REC in training age (p=.008), hours per week spent lifting (p<.001), types of lifting equipment primarily used (p<.001), lifting session duration (p<.001), average number of exercises per session (p<.001), average number of working sets per session (p<.001), how close to failure trained per set (p<.001), average rest between sets (p<.001), lifting style category (p<.001), least favorite style of training (p=.005), and current status of following a structured, planned lifting program ($p<.001$). Of the respondents who reported following a structured, planned lifting program, there was no significant difference between RT and REC in whether someone else or the respondents wrote their training program ($p=.20$). Full training history and current resistance training practices are presented in Table 3-2.

Table 3-2 Exercise practice variables

Exercise practice variable	RT frequency n (%)	REC frequency n (%)	df	X^2	*p*
Training Age**			10	23.3	.008
≤ 1 year	280 (14.20)	66 (18.86)			
2 years	265 (13.44)	45 (12.86)			
3 years	301 (15.26)	44 (12.57)			
4 years	196 (9.94)	36 (10.29)			
5 years	201 (10.19)	46 (13.14)			
6 years	139 (7.05)	20 (5.71)			
7 years	93 (4.72)	7 (2.00)			
8 years	83 (4.21)	4 (1.14)			
9 years	51 (2.59)	7 (2.00)			
10 years	79 (4.01)	13 (3.71)			
Over 10 years	284 (14.40)	61 (17.43)			
Hrs/Week Lifting***			3	969.63	<.001
1-2	238 (12.07)	310 (88.57)			
3-4	945 (47.92)	30 (8.57)			
5-6	603 (30.58)	9 (2.57)			
≥ 7	185 (9.38)	0 (0.00)			
Types of Lifting Equipment***			4	215.54	<.001
Body weight	60 (3.04)	72 (20.57)			
Free weights	1755 (89.00)	230 (65.71)			
Machines	116 (5.88)	27 (7.71)			
Resistance bands	18 (0.91)	18 (5.14)			
Other	22 (1.12)	3 (0.86)			

Lifting Session Duration* **			3	356.2	<.001
Less than 30 minutes	53 (2.69)	98 (28.00)			
Between 30 and 59 minutes	1151 (58.37)	211 (60.29)			
Between 1 hour and 1 hour 3 minutes	699 (35.45)	40 (11.43)			
Longer than 1 hour 30 minutes	66 (3.35)	1 (0.29)			
Average Number of Exercises Per Session* **			3	40.38	<.001
≤ 4	232 (11.77)	79 (22.57)			
5-8	1470 (74.54)	250 (71.43)			
9-12	244 (13.37)	18 (5.14)			
≥ 13	24 (1.22)	3 (0.86)			
Average Number of Working Sets Per Session* **			2	74.81	<.001
1	16 (0.81)	12 (3.43)			
2-3	1410 (71.50)	310 (88.57)			
≥ 4	544 (27.59)	28 (8.00)			
How Close to Failure Do You Train Per Set?* **			5	57.42	<.001
≥ 7 repetitions short of failure	42 (2.13)	23 (6.57)			
4-6 repetitions short of failure	200 (10.14)	62 (17.71)			
3 repetitions short of failure	466 (23.63)	91 (26.00)			
2 repetitions short of failure	760 (38.54)	82 (23.43)			
1 repetition short of failure	385 (19.52)	65 (18.57)			
I always train to or past failure	113 (5.73)	27 (7.71)			
Average Rest Between Sets* **			4	50.83	<.001
≤ 30 seconds	130 (6.59)	52 (14.86)			
Between 30 and 59 seconds	733 (37.17)	162 (46.29)			
Between 1 minute and 1 minute 59 seconds	795 (40.31)	106 (30.29)			
Between 2 minutes and 2 minutes 59 seconds	240 (12.17)	24 (6.86)			

≥ 3 minutes	73 (3.70)	6 (1.71)			
Lifting Style Category* **			6	111.15	<.001
Bodybuilding (free weights and machines for each muscle group with moderate load and reps)	963 (48.83)	150 (42.86)			
CrossFit (workouts of the day, barbell, body weight, and aerobic training combined with little rest)	226 (11.46)	32 (9.14)			
Powerlifting (heavy squat, bench press, and deadlift training)	453 (22.97)	36 (10.29)			
Olympic weightlifting (heavy snatch, clean, and jerk training)	14 (0.71)	1 (0.29)			
Machine circuits (multiple resistance training machines done in a series with little rest)	57 (2.89)	21 (6.00)			
Outdoor bootcamps (portable equipment like bands, body weight, and calisthenics training)	127 (6.44)	71 (20.29)			
Other	14 (0.71)	39 (11.14)			
Least Favorite Style of Training**			6	18.36	.005
Bodybuilding (free weights and machines for each muscle group with moderate load and reps)	88 (4.46)	14 (4.00)			
CrossFit (workouts of the day, barbell, body weight, and aerobic training combined with little rest)	419 (21.25)	84 (24.00)			
Powerlifting (heavy squat, bench press, and deadlift training)	100 (5.07)	24 (6.86)			
Olympic weightlifting (heavy snatch, clean, and jerk training)	460 (23.33)	106 (30.29)			
Machine circuits (multiple resistance training machines done in a series with little rest)	371 (18.81)	51 (14.57)			
Outdoor bootcamps (portable equipment like bands, body weight, and calisthenics training)	472 (23.94)	59 (16.86)			
Other	57 (2.89)	10 (2.86)			
Currently Following a Structured, Planned Lifting Program* **			2	407.82	<.001
No	423 (21.45)	200 (57.14)			
Yes	1256 (63.69)	19 (5.43)			
Yes but not consistently	293 (14.86)	131 (37.43)			
Who Wrote Your Resistance Training Program			1	1.64	.20

I put together my own	426 (27.54)	34 (22.67)
Someone else made it	1121 (72.46)	116 (77.33)

* = Significantly different frequency response between ST and RT, $p < 0.05$ determined by Chi-square test.

** = Significantly different frequency response between ST and RT, $p < 0.01$ determined by Chi-square test.

*** = Significantly different frequency response between ST and RT, $p < 0.001$ determined by Chi-square test.

Resistance training preferences

Resistance training preferences between RT and REC were compared using an independent samples *t*-test. On a scale from 1 to 5 with 1 = strongly disagree and 5 = strongly agree, RT scored significantly higher than REC on the following factors: presence of instructions/planning ($t(2320) = 5.08$, $p<.001$), ability to perform resistance training exercises ($t(2320)=19.72$, $p<.001$), and routine ($t(2320) = 4.50$, $p<.001$). Meanwhile, REC scored significantly higher than RT on the following factors: resistance training with family/friends – program flexibility ($t(2320) = -6.85$, $p<.001$), resistance training alone, ($t(2320) = -3.58$, $p<.001$). Notably, RT scored significantly higher than REC for the item "I like to resistance train" ($t(2320) = 22.71$, $p<.001$). There was no significant difference found between RT and REC for resistance training in fitness centers – similar age ("I like to resistance train at a community fitness center" and "I like to resistance train with other people of similar age.). Full results are displayed in Table 3-3.

Table 3-3 Mean level of agreement with resistance training preference factors

Resistance training preference factor	RT	REC	*df*	*t*	*p*	Effect size (Cohen's d)
Presence of instructions/planning	3.66 ± 0.48	3.52 ± 0.47	2320	5.08	<.001	0.30
Ability to perform resistance training exercises	4.49 ± 0.56	3.83 ± 0.67	2320	19.72	<.001	1.14
Resistance training with family/friends - program flexibility	3.04 ± 0.52	3.25 ± 0.57	2320	-6.85	<.001	0.40
Resistance training in fitness centers - similar age	2.82 ± 0.83	2.82 ± 0.85	2320	-0.09	0.93	0.01
Resistance training alone	3.44 ± 0.72	3.59 ± 0.69	2320	-3.58	<.001	0.21
Routine	3.35 ± 0.84	3.13 ± 0.87	2320	4.50	<.001	0.26

Mean level of agreement is based on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Data are presented as mean ± SD.

Perceived benefits

One-way ANOVA revealed significant differences ($p<.001$) between RT, REC, and NRT on all four of the perceived benefit factors: social, psychological, body image, and health. Post-hoc Tukey tests revealed that all groups differed significantly ($p<.001$) across all four factors except for REC and NRT when comparing the social benefit factor, the psychological benefit factor, and the body image factor; and REC and NRT when comparing the health benefit factor. See Table 3-4 for full results.

Table 3-4 Mean level of agreement with perceived benefits and barriers to resistance training

Factor	RT	REC	NRT
Benefits - Social[^]	2.91 ± 0.85	2.52 ± 0.77[~]	2.53 ± 0.73[~]
Benefits - Psychological[^]	4.35 ± 0.50	3.98 ± 0.57[~]	3.87 ± 0.58[~]
Benefits - Body Image[^]	4.23 ± 0.56	4.02 ± 0.56[~]	4.07 ± 0.62[~]
Benefits - Health[^]	4.20 ± 0.49	4.05 ± 0.47[~]	4.02 ± 0.48[~]
Barriers - TimeEffort[*]	2.00 ± 0.72	2.96 ± 0.69[$]	3.11 ± 0.69[$]
Barriers - Physical[*]	1.79 ± 0.65	2.33 ± 0.77[$]	2.56 ± 0.78[$]
Barriers - Social[*]	1.80 ± 0.74	2.13 ± 0.91[$]	2.35 ± 0.93[$]
Barriers - Specific[*]	1.91 ± 0.65	2.45 ± 0.70[$]	2.55 ± 0.67[$]

Mean level of agreement is based on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Data are presented as mean ± SD.

[^]Significant difference as indicated by one-way ANOVA, see Supplementary Table 3-1

[~]Significant difference as indicated by post-hoc Tukey test, see Supplementary Table 3-2

[*]Significant difference as indicated by one-way ANOVA, see Supplementary Table 3-3

[$]Significant difference as indicated by post-hoc Tukey test, see Supplementary Table 3-4

Perceived barriers

One-way ANOVA revealed significant differences (p<.001) between RT, REC, and NRT on all four of the perceived barrier factors: time-effort, physical, social, and specific. Post-hoc Tukey tests revealed that all groups differed significantly across all factors ($p \leq 0.01$) except for REC and NRT in the specific barrier factor (p=.08).

Section 4: Discussion

Previous research indicates that women's participation in resistance training remains relatively low despite its many physical and mental health benefits. Thus, the purpose of this study was to better understand women's current resistance training practices and preferences as well as their perceived benefits and barriers to resistance training. As hypothesized, RT expressed greater preference for lifting compared to REC, and RT perceived the benefits to be greater and barriers to be less than both NRT and REC.

RT expressed greater preference for instruction and planning, greater perceived ability to perform exercises, and stronger routine when it came to resistance training compared to REC. Additionally, RT reported spending more hours per week lifting weights, for longer duration per session, and were following a structured, planned lifting program. These results are consistent with previous research demonstrating that planning promotes exercise behavior [160]. Higher self-efficacy, the belief that individuals hold about their own capabilities to execute behaviors, is predictive of meeting resistance training recommendations [161-163], which further aligns with our results.

RT reported the highest perceived benefits of resistance training across every domain (social, psychological, body image, and health) while simultaneously reporting the lowest perceived barriers (time effort, physical, social, and specific) compared to both REC and NRT. REC did not report significantly different perceived benefits compared to NRT in the social, body image, and health factors or for specific barriers, suggesting greater similarity in perceived benefits and barriers between those who resistance train inconsistently and those who do not resistance train at all. The effect sizes of the one-way ANOVA for benefit factors indicate that the discrepancy difference between groups, though significant, was small, and the data reveal that even in REC and NRT, perceived psychological, body image, and health benefits of resistance training were rated approximately 4 out of 5 on the Likert scale, reflecting agreement with the benefits across groups. Previous research found that women who did and did not resistance train did not differ in terms of perceived psychological, body image, social, and health benefits related to resistance training [10]. However, it should be noted that the sample size ($n = 100$) was much smaller than the present study. Nevertheless, it is evident that RT, REC, and NRT all understand there are meaningful benefits associated with resistance training.

RT reported the lowest barriers to resistance training across every factor (time-effort, physical, social, and specific). REC also scored significantly lower than NRT for every factor except for specific. Similar to the findings of Harne and Bixby [10], the data from the current study show that time-effort was the highest barrier, with physical, social, and specific barriers scoring slightly lower across all groups. These results conflict with those of Peters et al. who found social barriers to be most reported amongst participants – specifically, concern with what people think of them and feeling like they were violating gender expectations due to muscle and strength being traditionally viewed as masculine [12]. This could be explained by the fact that the participants in that study were females aged 19.7 ± 1.5 years, thus they may have heightened evaluation concerns [155] compared to the participants in our study who were mostly between the ages of 25 and 34. Alternatively, as participants in our study were recruited through social media platforms, it may be the case that our participants were more familiar with fitness content via social media and thus experienced fewer social barriers as a result of women resistance training being more normalized, or even that interventions in recent years have made meaningful strides in making women feel more welcome and less judged in the weight room compared to before.

A 2022 systematic review and meta-synthesis of 402 participants across 20 total studies found that the most frequently observed barriers were social (gender-based stigmas, discouragement, and negative comments), while factors that facilitated resistance training engagement included social support, words of affirmation, and accompaniment [50]. Specifically, women expressed common concerns such as being perceived as 'princesses' and feeling self-conscious around others. Additional barriers included boredom, limited knowledge of resistance training, lack of supervision or routine, and struggling to balance family and work life. The authors emphasized the importance of ensuring gym environments are more welcoming to women and reducing gender-focused criticism to increase resistance training participation in women. This meta-synthesis was a collation of small sample size studies, thus the present observations using homogenous questions with an n = 2,741 may better reflect the current attitudes and perceptions of women towards resistance training.

There were certain limitations within this study. Two of the authors had large social media accounts used to communicate and promote fitness, resistance training, nutrition, and exercise information to the public, with ERH having approximately 170k followers on Instagram, of which 25% were female, and SLC having 400k followers, of which 83% were female. Thus, the participants who took this survey were likely not a representative, random sample from the broader population of women. Notably, while 85% of respondents reported engaging in some degree of resistance training, surveys of the general public indicate a 25-27% participation rate. The participant pool was also limited to those recruited from social media with a sample of predominantly normal-weight women between the ages of 18 and 44 residing in the United States, thus generalizability to other weight categories, ages, and other regions of the world is cautioned, as is generalizing to those not active on social media platforms. Additionally, there may have been some inherent bias introduced in this sample such that those who are interested in the topic of resistance training in women may have been more inclined to complete the survey. It is possible that those not currently resistance training opted not to participate in the study due to lack of interest in the topic.

Even so, while this sample may not be proportionally representative of the women who participate in resistance training at large, it is a large sample size and likely does present accurate data on the preferences as well as perceived benefits and barriers in women who do and do not resistance train.

All measures were self-reported and relied on participant recall. Further, there may be other variables that impact participants' perceived benefits and barriers to resistance training that were not captured in the questionnaire with the existing measures. These limitations should be taken into consideration when interpreting the findings of this research.

Future research should utilize a more diverse sample that includes more participants outside of the United States, of different age groups, and representing a greater diversity of body weights. Additionally, extra effort should be made to recruit participants who are not currently resistance training to better understand their perceived barriers. Finally, additional research should also focus on the differences in preferences and perceived benefits and barriers to resistance training in men versus women to better understand the discrepancy in participation rates.

Section 5: Practical applications

It appears that all respondents who took the survey, regardless of whether they resistance trained, understood the numerous benefits associated with resistance training. Thus, greater emphasis should be placed on addressing the barriers that women face to resistance training to increase participation and adherence rates. A multi-pronged approach to reduce the perceived time-effort, physical, social, and specific barriers is recommended.

Promoting resistance training programs for women that are shorter in duration, utilize limited equipment, and/or can be completed in the comfort and privacy of their own homes may be effective strategies to overcome the time-effort barrier. For example, a busy working mother may be more willing to do a 20-

minute resistance band or DB-only session in her living room in between her many other responsibilities throughout the day. Time-saving training strategies such as CT, supersets, and dropsets can also be encouraged so women can complete effective workouts even if time is a limiting factor.

Providing more beginner-level workouts and tutorials that are simple and limit fatigue may help encourage participation among women who are hesitant to lift weights due to their aversion to discomfort, or who are self-conscious during exercise. To further increase competence and confidence, connecting women with mutual interest in resistance training, either in-person or virtually, can help foster community, group learning, and a sense of belonging.

Further, there are a myriad of steps that can be taken within the gym space to lower barriers that women face as they engage in resistance training. To combat the image that the weights section of the gym is a male-dominated space, more female trainers can be hired and more women's only areas of gyms or women's only workshops or courses can be created. Gyms can also reconfigure the layout and messaging to make them more inclusive of women, and no-tolerance policies against harassment or intentional intimidation can be implemented.

The above interventions may help to change women's attitudes and self-efficacy around resistance training, thereby increasing participation rates over time. This can ensure that more women reap the many physical and mental benefits of resistance training and experience a better quality of life.

Supplementary Table 3-1 One-way ANOVA for benefit factors

Factor	df	SS	F	*p*	ES
Social	2	83.25	61.54	<.001	0.04
Residuals	2738	1851.80			
Psychological	2	53.34	197.14	<.001	0.13
Residuals	2738	740.84			
Body image	2	19.02	29.05	<.001	0.02
Residuals	2738	896.55			
Health	2	15.04	32.30	<.001	0.02
Residuals	2738	637.37			

Supplementary Table 3-2 Post-hoc Tukey comparisons for benefit factors

Factor		Mean Difference	SE	t	p_{tukey}
Social					
NRT	REC	0.01	0.06	0.13	.99
	RT	-0.384	0.04	-8.69	<.001***
REC	RT	-0.392	0.05	-8.22	<.001***
Psychological					
NRT	REC	-0.12	0.04	-3.10	.05
	RT	-0.49	0.03	-17.40	<.001***
REC	RT	-0.37	0.03	-12.27	<.001
Body Image					
NRT	REC	0.04	0.04	1.06	.54
	RT	-0.16	0.03	-5.31	<.001***
REC	RT	-0.21	0.03	-6.26	<.001***
Health					
NRT	REC	-0.02	0.04	-0.67	.78
	RT	-0.18	0.03	-6.74	<.001***
REC	RT	-0.15	0.03	-5.41	<.001***

*$p<.05$
**$p<.01$
***$p<.001$

Supplementary Table 3-3 One-way ANOVA for barrier factors

Factor	df	SS	F	*p*	ES
TimeEffort	2	596.00	586.77	.00	0.30
Residuals	2738	1390.52			
Physical	2	251.72	269.65	.00	0.17
Residuals	2738	1277.94			
Social	2	120.65	95.31	.00	0.07
Residuals	2738	1733.05			
Specific	2	198.41	230.35	.00	0.14
Residuals	2738	1179.18			

Supplementary Table 3-4 Post-hoc Tukey comparisons for barrier factors

Factor		Mean Difference	SE	t	p_{tukey}
TimeEffort					
NRT	REC	0.15	0.05	2.92	0.01*
	RT	1.10	0.04	28.76	<.001***
REC	RT	0.95	0.04	23.04	<.001***
Physical					
NRT	REC	0.23	0.05	4.57	<.001***
	RT	0.76	0.04	20.88	<.001***
REC	RT	0.54	0.04	13.58	<.001***
Social					
NRT	REC	0.22	0.06	3.88	<.001***
	RT	0.55	0.04	12.85	<.001***
REC	RT	0.33	0.05	7.07	<.001***
Specific					
NRT	REC	0.10	0.05	2.16	0.08
	RT	0.64	0.04	18.20	<.001***
REC	RT	0.54	0.04	14.18	<.001***

*p<.05
**p<.01
***p<.001

Chapter 4 Acute effects of high intensity circuit versus traditional strength training on physiological and psychological outcomes in trained women

Prelude

As covered in Chapter 3, RT reported greater preference for lifting and also perceived greater benefits and lower barriers to lifting compared to REC and NRT. Interestingly, all participants regardless of training status understood there were meaningful benefits associated with resistance training, suggesting that it was the perceived barriers rather than lack of perceived benefits that held some women back from regularly lifting. Next, the purpose of Chapter 4 was to ascertain the acute physiological and psychological impacts of HICT versus TS in trained women.

Section 1: Introduction

While participation rates of women in resistance training have been increasing over the years [36], relatively little is known about the physiological and psychological effects of the various styles of resistance training. This may be a relevant factor as distinct styles of resistance training may differ in appeal by demographic, subsequently producing different adherence rates. Depending on whether the perceived barrier to adherence is time availability, equipment availability, personal preference or enjoyment, or some other factor which varies between resistance training styles, women may choose one form of resistance training over another. Thus, a better understanding of the initial, acute responses to resistance training is important to positively influence participation.

TS is a popular style of training that typically involves performing one exercise at a time with moderate to heavy loads at typically 65% to 90% of their 1RM [92], taking long rest periods (2-3 minutes or more), and completing all sets of one exercise before moving onto the next. In contrast, CT involves completing a sequence of exercises back-to-back with little to no rest in between sets. Whereas typical CT is performed with lower loads at typically 40% to 60% 1RM, usually not to failure [71], HICT is a form of CT that entails pushing sets closer to muscular failure and thus is more effective at increasing BMD and maximal strength [81]. CT is more time efficient and has increased cardiorespiratory fitness benefits compared to TS [71, 75, 76]. To elucidate the acute differences between CT and TS, various physiological and psychological metrics need to be measured.

BLA is one of the most commonly measured parameters during exercise and performance testing [164]. Lactate is a proxy of exercise intensity and energetic demand, as high BLA levels reflect the lactate accumulation from anaerobic energy production [165, 166]. A dramatic increase in BLA during exercise indicates that the rate at which lactate can be removed from the blood is exceeded by the rate at which it enters the blood [164]. The energetic demand of BLA removal is one of the causes of EPOC, thus higher BLA from exercise can increase EPOC [167, 168]. While a prior study examined the acute effects of traditional CT on BLA in women [168], this was not compared directly with TS.

Session rating of perceived exertion (sRPE) is a modified version of the traditional RPE scale that correlates to global exercise intensity and can be used to reflect the demands of high intensity aerobic and resistance exercise [169]. sRPE is a reliable metric for gauging session overall difficulty, as it uniquely and succinctly describes the aggregated experience of an entire resistance training session. It scales with load and proximity to failure [170], volume [171], and work rate [172], which comprise the variables that increase session difficulty. Further, sRPE correlates with increases in HR and BLA [170, 173]. The values for sRPE range from 0 to 10, with 0 correlating to "rest" and 10 correlating to "maximal" RPE. Given that rest intervals differ between CT and TS, this may produce differing sRPE values, although this has not been investigated in resistance-trained women.

In addition to the perceived difficulty of training sessions, other emotional responses may influence exercise participation and adherence. Anxiety is an aversive emotional and motivational state characterized by an overwhelming sense of fear, worry, and apprehension that typically arises when an individual doubts their ability to cope with a situation [174]. This can often decrease cognitive function, specifically in terms of short-term memory and reasoning deficits [175]. It is also a risk factor for numerous physical health problems (e.g. cardiovascular disease) [176, 177], lower health-related quality of life [178], and increased all-cause mortality [179]. State anxiety refers to the currently experienced level of anxiety and is determined by trait anxiety as well as by situational stress [180]. Previous research has shown that while acute aerobic exercise reduced state anxiety, acute resistance exercise did not, and the authors thus concluded that acute resistance exercise may not be an effective means of reducing state anxiety [181]. Conversely, other research has shown that when measuring state anxiety at numerous time points including up to 120 minutes after the exercise bout, resistance exercise reduced state anxiety [182, 183]. No study thus far has directly compared the impact of acute HICT versus acute TS on state anxiety.

Finally, self-efficacy, which refers to an individual's belief in their own capacity to do things, is also a key factor in predicting exercise behavior [48, 49]. Specifically, a higher level of self-efficacy makes it more likely that an individual will both begin and continue adhering to an exercise program [184], which can positively influence psychological well-being [185]. There is a consistent positive relationship between self-efficacy and resistance training participation [186]. Though HICT and TS are two popular forms of resistance training amongst women, the acute physiological and psychological impacts of these training modalities may differ in terms of the above variables and have yet to be directly compared. Therefore, the aims of this study were two-fold: 1) to determine if acute physiological outcomes were different between HICT and TS, and 2) to determine if acute psychological outcomes were different between HICT and TS. It was hypothesized that HICT would produce increased measures of BLA, HR, and sRPE as well as greater state anxiety compared to TS.

Section 2: Methods

Experimental approach to the problem

To compare acute physiological and psychological outcomes between HICT and TS in resistance-trained women, a short-term crossover study was conducted. Participants were recruited by emailing a University campus listserv, posting fliers across the campus, and posting fliers online through various social media platforms.

Subjects

A total of 26 women participated in the study. To be included, women must have been between the ages of 18 and 40 years old, trained (>6 months of resistance training experience, engaging in resistance training a minimum of twice a week), healthy, and free from musculoskeletal injury. Participants agreed not to take ergogenic aids, supplements, or medications that might affect resistance training performance (e.g. creatine, pre-workout). Participant characteristics are summarized in Table 4-1. The methods and procedures used in this study were approved by Auckland University of Technology Ethics Committee, AUTEC Reference number 22/16 and also by the California State University San Marcos Institutional Review Board (IRB) #1925058-1.

Table 4-1 Participant characteristics

Demographic Variable	Frequency *n* (%)
Age	
18-24	3 (11.5)
25-34	19 (73.1)
35-44	4 (15.4)
Resistance Training Experience (years)	
1 or less	5 (19.2)
2	4 (15.4)
3	1 (3.8)
4	2 (7.7)
5	4 (15.4)
6	2 (7.7)
7	2 (7.7)
8	1 (3.8)
9	3 (11.5)
10 or more	2 (7.7)
Hours Resistance Training Per Week	
1-2	13 (50.0)
3-4	5 (19.2)
5-6	8 (30.8)
Type of Resistance Training Equipment Primarily Used	
Body weight	4 (15.4)
Free weights	18 (69.2)
Machines	3 (11.5)
Other	1 (3.8)

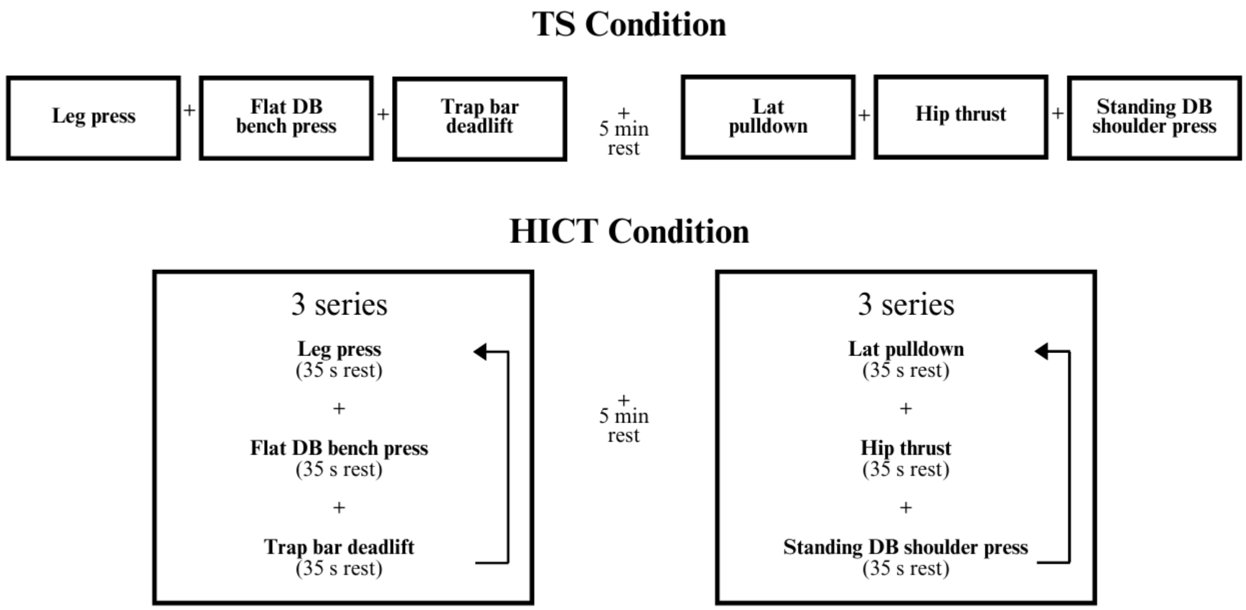
Procedures

Participants attended four total sessions over a span of 8-11 days. Participants were advised to continue their usual diet and fuel like they normally would before their workout. However, dietary data was not collected or analyzed. The first session consisted of familiarization in which the participants completed a dynamic warm-up as well as one set of each exercise (leg press, flat DB bench press, trap bar deadlift, lat pulldown, hip thrust, and standing DB shoulder press). Exercise exertion was selected using the Borg CR10 scale which rates exertion from 0 (rest) to 10 (maximal effort) [187], and participants were asked to maintain a 5-7 rating between the 8 to 15 repetition range.

The second session took place 24-48 hours after familiarization and consisted of 3-repetition maximum (3RM) testing for each exercise. Following a 5-minute steady-state cardiovascular warm-up consisting of walking on a treadmill, participants performed a 5-minute dynamic sequence consisting of 10 repetitions each of the lateral squat, bent over thoracic spine rotation, quadricep stretch to hamstring reach, body weight windmill, and dynamic shoulder circle. They then completed 2 sets of 5-8 repetitions of each exercise at a submaximal load with 2 minutes of rest between sets. This load was selected based on the participants' reported loads and number of repetitions lifted as well as perceived exertion during their typical lifting sessions. Then, an initial load was lifted for 3 repetitions that was within an estimated 50-70% of the participants' capacity, gauged by prior experience of the participants as well as the investigator who is a certified strength and conditioning specialist through the NSCA. After a weight was successfully lifted, the participants were allowed to rest 3-5 minutes before attempting another lift with additional load increased by 1.25 to 20kg (depending on the exercise, participant strength, and difficulty of the prior set) for 3 repetitions. The final, heaviest weight lifted successfully for 3 repetitions was determined as their 3RM, or if fewer repetitions were completed, this load and repetition combination was used to calculate their 3RM [188].

The third session took place a minimum of 72 hours after the 3RM testing session. During this visit, participants were randomly assigned via coin flip to one of two crossover conditions: 1) HICT condition - 35 seconds' rest between sets, exercises completed "vertically" (one set completed per exercise before moving to the next exercise) in two separate 3-exercise series; 2) TS training – 3 minutes' rest between sets, exercises completed one at a time. Both conditions completed 3 working sets of 8 to 15 repetitions of each exercise. See Figure 4-1 for a description of the HICT and TS protocols.

Figure 4-1 Summary of 4 total visits.



Experimental design: TS performed 3 sets of each exercise one at a time with a 3-minute rest between sets, and a 5-minute rest allowed after the 3rd exercise; HICT performed 3 series of 2 circuits with a 5-minute rest.

Following a 5-minute steady-state cardiovascular warm-up and 5-minute dynamic warm-up, participants completed the first arm of the crossover they were randomly assigned to (HICT or TS). Each exercise was performed for 3 sets of 8 to 15 repetitions using a load that was challenging within the prescribed repetition range dictated by the Borg CR10 range of 8 to 9, with 0 corresponding to “rest” and 10 corresponding to “maximal” exertion. Load was increased or decreased accordingly in subsequent sets as needed to maintain the appropriate effort in the target repetition range. The repetitions were performed at a self-selected tempo without formal instruction beyond a controlled eccentric phase and a forceful concentric phase. Participants’ lactate was measured via a small blood sample taken from a punctured capillary on a fingertip using a Lactate Plus handheld portable lactate meter (Nova Biomedical, Waltham, MA, USA). Additionally, participants wore Polar M400 watches (Polar Inc., Lake Success, NY, USA) to measure HR via wrist-based photoplethysmography. Measurements for both BLA and HR were taken immediately pre-training (within 1 minute), mid-session, and immediately post-training (within 1 minute).

Upon completion of the training session, participants were instructed to sit in a quiet area for approximately 10 minutes before completing questionnaires on a laptop computer via Qualtrics. The questionnaires assessed psychological states at 4 different time points: before exercise (10 minutes pre-session), mid-session, then 2 more times after exercise (5 minutes post-session, 10 minutes post-session). At the 15-minute post-session mark, each participant recorded their sRPE by answering the question, “How was your workout?” using the sRPE scale (Table 4-2).

Table 4-2 sRPE rating and descriptor

RPE rating	**Descriptor**
0	rest
1	very, very easy
2	easy
3	moderate
4	somewhat hard
5	hard
6	
7	very hard
8	
9	
10	maximal

State Anxiety. State anxiety was measured using the Abbreviated 6-Item State Trait Inventory (STAI). This is a 6-item questionnaire that measures state anxiety (how one feels at the moment) and is the short form scale of the original 20-item questionnaire widely used in exercise research. Participants rated their responses on a 4-point Likert scale ranging from “not at all” to “very much so”. This version is recommended when time is a limitation, as in the case of our study. The questionnaire responses were added together to form a total score, with some responses being reverse coded. The short form of the STAI has adequate internal consistency, with the reliability coefficient α ranging from 0.77 to 0.82 [189].

Exercise Self-Efficacy. A modified version of the Exercise Self-Efficacy Scale was used to ascertain the degree of confidence the participants possessed to successfully complete the specified exercise routine for each of the crossover conditions [190]. The scale consists of 9 items, each item representing an exercise condition. Participants were asked about their beliefs in their ability to “successfully complete all exercises without deviating from pacing.” The total score was calculated by summing the responses to each question, then dividing by the total number of items in the scale. The modified version of the Exercise Self-Efficacy Scale has high internal consistency coefficients α ranging above 0.90 [190].

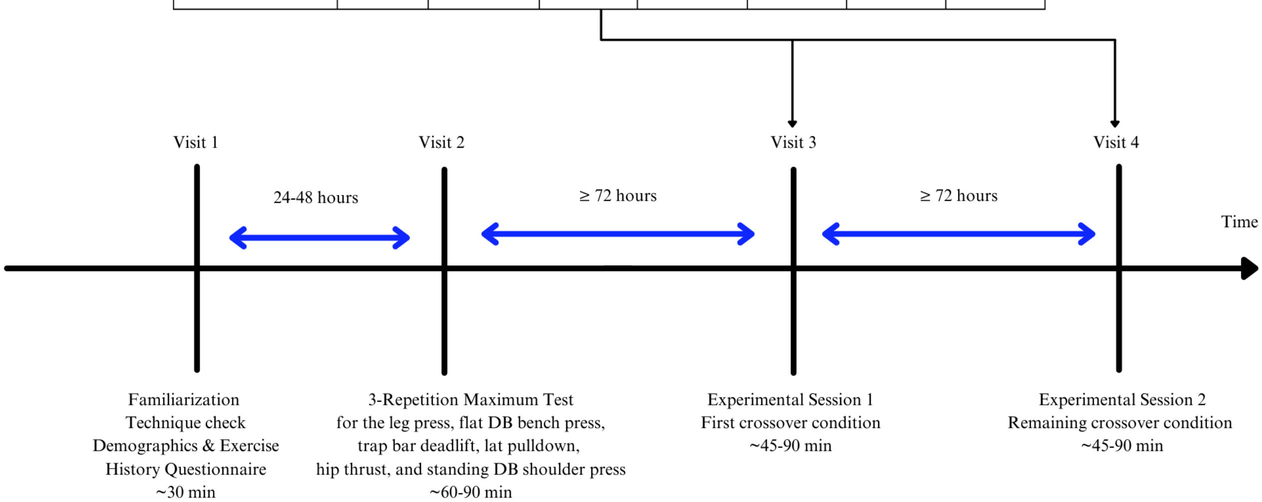
sRPE. The modified Borg CR10 scale for sRPE was administered 15 minutes post-training to assess the perceived overall difficulty of the session [191].

The fourth and final session took place a minimum of 72 hours after the third session. During this visit, the remaining crossover condition was completed following the same steps as outlined above.

A schematic of the experimental timeline including the physiological and psychological measurements are outlined in Figure 4-2.

Figure 4-2 Summary of 4 total visits

	10min pre-session	Pre-session (within 1min)	Mid-session	Post-session (within 1min)	5-min post-session	10-min post-session	15-min post-session
Heart rate	ongoing						
Lactate		X	X	X	X		
State anxiety	X		X			X	
Exercise self-efficacy	X		X				
Session RPE							X



Statistical analyses

To analyze aim 1, a repeated measures ANOVA was conducted to examine the difference in BLA and HR levels between the two conditions pre- and post-testing session. Post hoc Bonferroni pairwise analyses were conducted for BLA as there was a significant main effect of time to determine which pairs of groups were significantly different from one another and to reduce the potential for Type I error. A paired t-test was used to examine the difference in average and max HR between the two conditions.

To analyze aim 2, separate ANOVAs were used for each of the dependent variables. Baseline measures of the dependent variables were also entered as covariates in the model. A two-way repeated measures ANOVA was used to compare the difference in state anxiety and exercise self-efficacy scores at the different time points. Specifically, for state anxiety, the following outcome variables were entered as the repeated measures factors: 10-min pre-session score, mid-session score, and 10-min post-session score. Experimental condition (HICT or TS) was entered as the between-subjects factor. As the assumption of sphericity was violated, a Greenhouse-Geisser correction was applied. There was a statistically significant main effect of time, so post hoc Bonferroni pairwise analyses were run. Similarly, for self-efficacy, pre-session and mid-session scores were entered as the repeated measures factors with experimental condition entered as the between-subjects factor. As there was a significant main effect of time, post hoc Bonferroni pairwise analyses were also run. For sRPE, a paired t-test was used to compare scores between the two crossover conditions.

All analyses were completed using JASP (v 0.18.2).

Section 3: Results

Acute physiological outcomes

The results of the acute physiological outcomes are displayed in Table 4-3. For 3RM testing, the experimental condition denotes which training condition the participant completed during session 3 (i.e. HICT in session 3 and then TS in session 4 would be denoted as "HICT" and vice versa). No significant differences in 3RM were found between participants who performed HICT first and those who performed TS first. Average ($t(25) = 3.84$, $p<.001$) and max HR ($t(25) = 3.99$, $p<.001$) were significantly higher in the HICT condition compared to the TS condition.

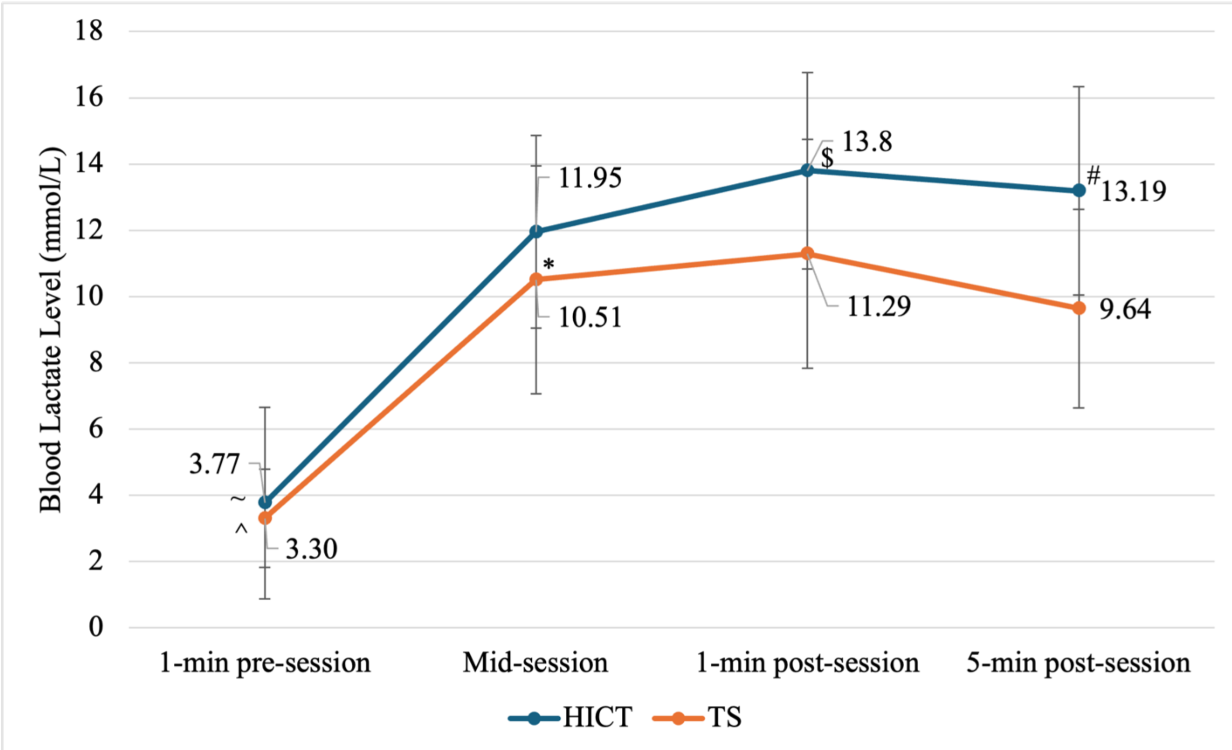
Table 4-3 Acute physiological outcomes

Outcome variable	All	HICT	TS	95% CI for group Lower	95% CI for group Upper	Effect size (Cohen's d)
3RM leg press (kg)	105.72 ± 42.47	113.05 ± 41.04	98.40 ± 44.26	-0.44	1.12	0.34
3RM flat DB bench press (kg)	28.82 ± 6.92	30.36 ± 8.76	27.29 ± 4.23	-0.34	1.22	0.45
3RM trap bar deadlift (kg)	76.15 ± 23.09	76.59 ± 28.01	75.72 ± 18.04	-0.73	0.81	0.04
3RM lat pulldown (kg)	41.66 ± 8.53	43.06 ± 8.59	40.27 ± 8.59	-0.45	1.10	0.33
3RM hip thrust (kg)	118.98 ± 34.93	126.13 ± 45.40	111.83 ± 19.23	-0.37	1.18	0.41
3RM standing DB shoulder press (kg)	22.75 ± 5.75	23.38 ± 6.37	22.12 ± 5.23	-0.56	0.98	0.22
Average HR (bpm)	117.90 ± 18.83	125.58 ± 19.69	110.23 ± 14.61†	0.31	1.45	0.89
Max HR (bpm)	151.94 ± 17.80	157.65 ± 16.72	146.23 ± 17.3†	0.11	1.23	0.67

For 3RM testing, the experimental condition denotes which training condition the participant did first in session 3.
Values are expressed as means ± standard deviation.
†significantly different from HICT

The results of BLA at different time points are displayed in Figure 4-3. Means and standard deviations for HICT were as follows for 1-min pre-session, mid-session, 1-min post-session, and 5-min post-session, respectively: 3.77 ± 2.89, 11.95 ± 2.91, 13.80 ± 2.97, 13.19 ± 3.14; and for TS: 3.30 ± 1.48, 10.51 ± 3.44, 11.29 ± 3.45, 9.64 ± 3.00. There was a statistically significant main effect of time ($F(3,147) = 174.53$, $p < .001$), group ($F(3,147) = 10.03$, $p = .003$), and an interaction between time and group ($F(1,49) = 4.53$, $p = .005$) for BLA levels. Post hoc Bonferroni pairwise analyses revealed that HICT 1-min pre-session levels were significantly lower than all other conditions and timepoints ($p<.001$) except for TS 1-min pre-session ($p = 1.00$); TS 1-min pre-session levels were significantly lower than all other conditions and timepoints ($p<.001$); TS mid-session levels were significantly lower than HICT 1-min post-session ($p = .003$); HICT 1-min post-session levels were significantly higher than TS 5-min post-session ($p<.001$); and HICT 5-min post-session levels were significantly higher than TS 5-min post-session ($p = .001$). No significant differences in volume load (sets x reps x load) were found for any exercise between HICT and TS. Average volume load for each exercise by group are displayed in Table 4-4.

Figure 4-3 BLA levels over time



^Significant difference as indicated by post-hoc Bonferroni test, see Supplementary Table 4-1

~Significant difference as indicated by post-hoc Bonferroni test, see Supplementary Table 4-1

*Significant difference as indicated by post-hoc Bonferroni test, see Supplementary Table 4-1

$Significant difference as indicated by post-hoc Bonferroni test, see Supplementary Table 4-1

#Significant difference as indicated by post-hoc Bonferroni test, see Supplementary Table 4-1

Table 4-4 Training volume for each exercise by training condition

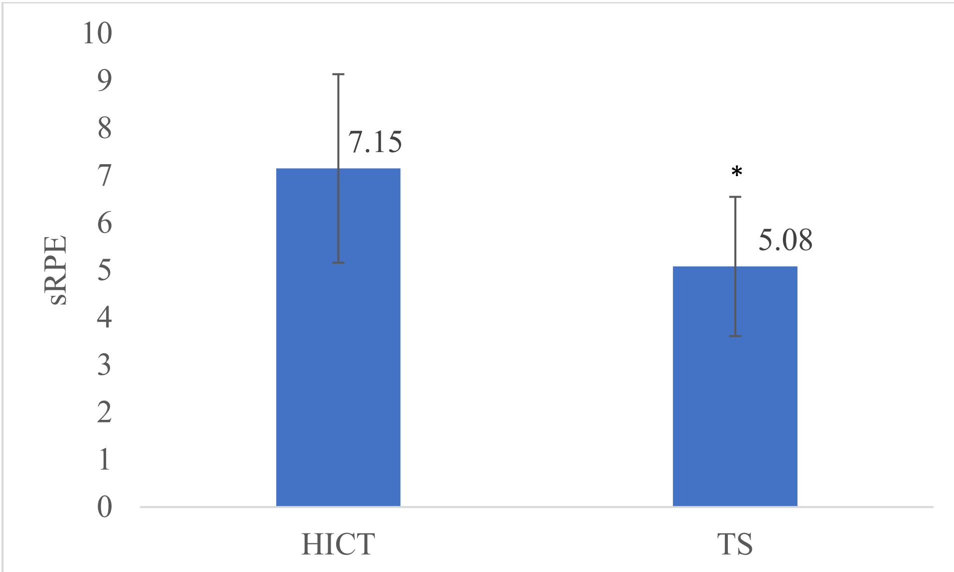
Exercise	HICT (load in kg)	TS (load in kg)	95% CI for group Lower	Upper	Effect size (Cohen's d)
Leg press	1687.12 ± 956.77	2311.89 ± 1446.49	1434.52	184.99	-0.51
Flat DB bench press	660.33 ± 219.85	700.20 ± 204.48	-179.57	99.83	-0.19
Trap bar deadlift	1550.69 ±710.83	1662.89 ±735.24	588.03	363.62	-0.16
Lat pulldown	796.70 ± 133.35	885.36 ± 146.63	-180.88	3.55	-0.63
Hip thrust	2058.23 ± 689.24	2775.36 ± 792.46	704.79	275.54	-0.29
Standing DB shoulder press	384.22 ± 111.60	458.03 ± 160.69	-164.84	17.21	-0.53

No significant differences were found between groups for any variables ($p > 0.05$).

Acute psychological outcomes

For HICT, sRPE was 7.15 ± 1.99; for TS, it was 5.08 ± 1.47. sRPE scores were significantly higher in HICT compared to TS, ($t(25) = 5.05$, $p<.001$) (Figure 4-4).

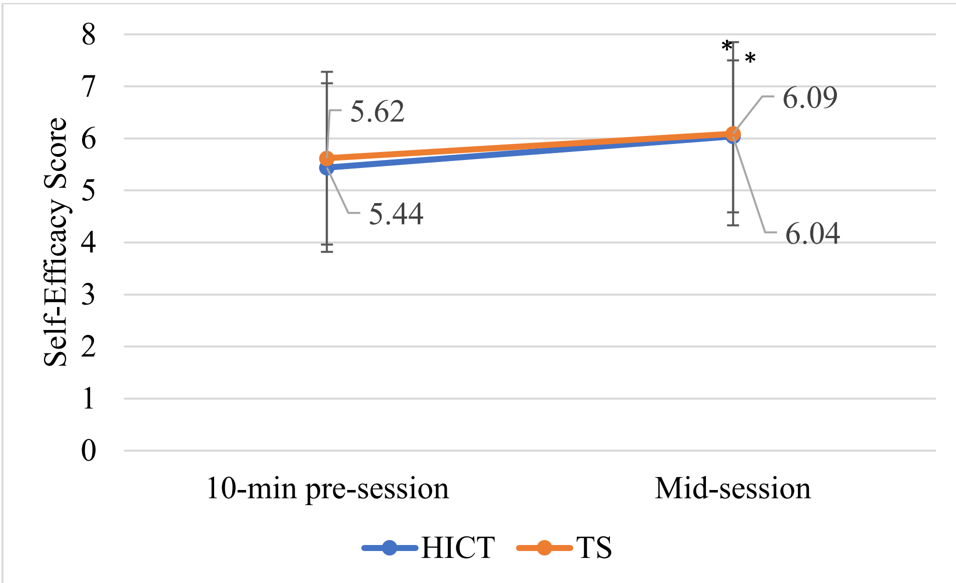
Figure 4-4 sRPE scores



*significantly different from HICT

Self-efficacy means and standard deviations for HICT pre- and mid-session, respectively, were as follows: 5.44 ± 1.62, 6.04 ± 1.46; for TS: 5.62 ± 1.67, 6.09 ± 1.76. There was a statistically significant main effect of time ($F(1,50) = 17.05$, $p<.001$), but group ($p=.80$) and interactions ($p = .61$) were not statistically significant. Post hoc Bonferroni pairwise analyses revealed that pre-session scores were significantly lower than mid-session scores across both groups ($p<.001$) (Figure 4-5).

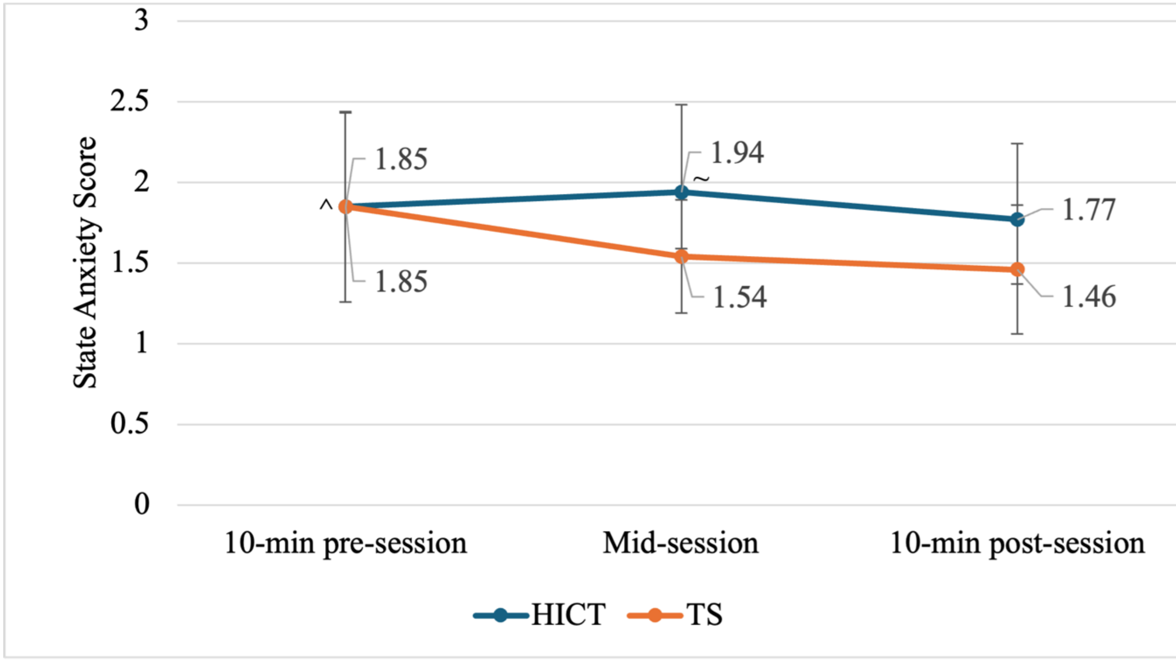
Figure 4-5 Self-efficacy scores



*significantly different from pre-session scores

For state anxiety, there was a statistically significant main effect of time ($F(1.68,84.99) = 4.94$, p=.01), group ($F(1,50)$=4.90, p=.03), and interactions ($F(1.68, 83.99)$=4.07, p=.03). Post hoc Bonferroni pairwise analyses revealed that TS 10-min pre-session was significantly higher than TS 10-min post-session (p=.01), and HICT mid-session was significantly higher than TS 10-min post-session (p=.01) (Figure 4-6).

Figure 4-6 State anxiety scores



^Significant difference as indicated by post-hoc Bonferroni test, see Supplementary Table 4-2
~Significant difference as indicated by post-hoc Bonferroni test, see Supplementary Table 4-2

Section 4: Discussion

The primary objective of this study was to compare the acute physiological and psychological responses to HICT vs. TS in trained women. The overall findings support the hypothesis that HICT had greater physiological (BLA, HR) and psychological (sRPE, state anxiety) stress compared to TS.

Our BLA results are similar to those of a previous study which found that the metabolic response to HICT was significantly higher compared to TS in male soccer players [98]. Additionally, other research in recreationally active women found that higher intensity forms of resistance training (specifically, aerobic circuit weight training and combined circuit weight-interval training) yielded higher BLA compared to traditional circuit weight training [168]. While the resistance training protocols in these studies did not exactly mirror those of our study, parallel comparisons can still be drawn as the higher intensity interventions led to increased BLA concentrations. These findings suggest that the anaerobic energy contribution is higher during HICT, thus it is possible that HICT can be employed as a useful stimulus to improve BLA tolerance and clearance, and ultimately improve anaerobic fitness.

Further, the greater average and max HR responses during HICT indicate greater cardiovascular load compared to TS. It should be emphasized that the per-set Borg CR10 RPE ratings were the same in both training conditions and training volume did not significantly differ between conditions. Thus, it is likely the circuit setup and short rest periods of HICT placed greater demands on the cardiovascular system. Of note, HR responses can be influenced not only by effort and rest period but also by exercise selection. For example, performing a set of trap bar deadlifts would place greater demands on the cardiovascular system than a set of bicep curls due to the difference in muscles that are recruited. Nevertheless, the HR results from this study indicate that HICT has the potential to lead to long-term cardiorespiratory improvements with continued practice.

Self-efficacy increased in both groups following their respective training sessions, which is important as there is a consistent positive relationship between self-efficacy and continued resistance training behavior [161, 192, 193]. In fact, self-efficacy is one of the strongest predictors of women meeting the resistance training recommendations of training two or more days per week alongside attitude, descriptive norms, perceived behavioral control, and intention [161]. The participant responses from our acute study thus may be indicative of a higher probability of continuing to resistance train. It is possible that in addition to the resistance training itself, an enjoyable training environment under the guidance of a qualified trainer contributed to this increase in self-efficacy [186, 194]. However, the ability of interventions to increase self-efficacy with the goal of improving resistance training participation has yet to be established [186].

Similar to the findings of previous research [170], the higher aerobic intensity of HICT compared to TS led to greater sRPE scores. It appears that sRPE values increase alongside training intensity. Thus, while each working set was performed at a Borg10 rating of between 8 and 9 for both experimental conditions, the shorter rest periods of HICT meant that participants were less recovered for each subsequent set. Likewise, the longer rest periods of TS meant that participants had more time to recover in between sets, which would explain the lower sRPE ratings. This is useful as sRPE is highly correlated with HR zones and overall training load and can be used to monitor individuals' efforts in their workouts. Of course, it should be noted that sRPE is subjective, and while physiological and neurological factors do impact sRPE value, so do other factors such as music, fitness level, instructions about and supervision over exercise, environmental temperature, and more [195].

The current body of literature on the impact of exercise type/intensity on state anxiety scores is mixed. Strickland and Smith examined the effects of single-bout resistance exercise on anxiety measures and reported mixed results: with exercise at higher intensities (i.e., >70% 1RM), state anxiety levels were less likely to decrease compared to exercise at low to moderate intensities (i.e., 50-70% 1RM) [196]. Rest intervals between sets may also be a factor, as low load exercise with longer rest periods (i.e., 50-55%

1RM and 90s) yields greater drops in state anxiety compared to higher load exercise with shorter rest periods (i.e., 80-85% 1RM and 30s) [140]. It should be noted, however, that in our study, participants in both conditions executed sets at moderately high load (roughly 70% 1RM), and the rest periods of TS were twice as long as that of Bibeau 2010 (90s compared to 180s). Additionally, females may be more sensitive to the anxiolytic effects of resistance exercise than males: female participants experienced robust drops in state anxiety when performing resistance exercise at either a self-selected or fixed load (75% 1RM) [182]. Most previous research thus points to low-to-moderate loads to maximize the anxiety-reducing effects of a single resistance exercise session, while our findings suggest that higher load resistance exercise can have similar anxiolytic effects.

The totality of our findings suggests that HICT was more demanding both physiologically and psychologically compared to TS. As HICT combines characteristics of both traditional CT and TS, it could be a useful training modality to improve women's strength and cardiovascular function. Indeed, research has shown that contrary to popular belief, HICT is equally as effective as TS at increasing body strength and muscular hypertrophy [79, 197]. Its primary benefit over TS would be its time-saving nature, with HICT sessions completed in approximately 50 to 60 minutes and TS completed in approximately 75 to 85 minutes. Therefore, for women who find higher perceived exertion a worthwhile trade-off for reducing workout length by roughly one third, HICT may be advised.

The primary limitation of this study was small sample size. Additionally, the findings of this study cannot necessarily be extrapolated to populations of different age groups, training experience, sex, or those performing a resistance training program with different training variables. Finally, the short-term nature of this research provides potential insights into long-term participation and adherence, but longitudinal research is necessary to confirm these insights. Future research should consider including other physiological measures of cardiovascular response, such as VO_2, and psychological measures such as affect (emotional experiences and feelings, both positive and negative), attitude, and perceived behavioral control.

Section 5: Practical applications

The present data show that HICT provides a more robust acute cardiovascular demand by reducing rest intervals, which also carries the benefit of reducing session length. Supervised HICT is equally as effective at inducing muscle and strength increases as TS, thus it could be a favorable training modality for individuals looking for more time-efficient workouts that are still physiologically effective.

Further, three other variables should be taken into consideration: 1) personal preference; not everyone may enjoy the higher perceived exertion stemming from the shorter rest periods, or someone may prefer the slower, longer-rest nature of TS despite the outcomes of this study, in which case they should not be discouraged from participating in their preferred training modality; 2) depending on the exercise selection, the equipment layout of the training venue, and the presence of other people, completing HICT with different exercises may be more difficult to execute from a logistical standpoint; and 3) the individual's capacity to sustain a higher work:rest ratio with HICT; participants were encouraged to maintain load-rep-RPE combinations each set, which may be challenging without supervision if an individual does not have this capacity.

Supplementary Table 4-1 Post hoc Bonferroni comparisons for BLA

	Mean difference (standard error)	95% CI for mean difference: Lower	95% CI for mean difference: Upper	t	Cohen's d	p_{bonf}
HICT, 1-min pre-session						
TS, 1-min pre-session	0.47 (0.83)	-2.19	3.12	0.56	0.16	1.00
HICT, mid-session	-8.18 (0.62)	-10.16	-6.21	-13.19	-2.76	<.001***
TS, mid-session	-6.74 (0.83)	-9.39	-4.09	-8.19	-2.27	<.001***
HICT, 1-min post-session	-10.04 (0.62)	-12.01	-8.06	-16.18	-3.38	<.001***
TS, 1-min post-session	-7.52 (0.83)	-10.17	-4.87	-9.06	-2.54	<.001***
CT, 5-min post-session	-9.42 (0.62)	-9.42	-7.45	-15.19	-3.18	<.001***
TS, 5-min post-session	-5.87 (0.83)	-8.52	-3.22	-7.07	-1.98	<.001***
TS, 1-min pre-session						
HICT, mid-session	-8.65 (0.83)	-11.30	-6.00	-10.41	-2.92	<.001***
TS, mid-session	-7.21 (0.63)	-9.22	-5.20	-11.39	-2.43	<.001***
HICT, 1-min post-session	-10.50 (0.83)	-13.15	-7.85	-12.64	-3.54	<.001***
TS, 1-min post-session	-7.99 (0.63)	-10.00	-5.98	-12.63	-2.69	<.001***
HICT, 5-min post-session	-9.89 (0.83)	-12.54	-7.24	-11.91	-3.34	<.001***
TS, 5-min post-session	-6.34 (0.63)	-8.35	-4.32	-10.02	-2.14	<.001***

HICT, mid-session						
TS, mid-session	1.44 (0.83)	-1.21	4.09	1.73	0.49	1.00
HICT, 1-min post-session	-1.85 (0.62)	-3.83	0.12	-2.99	-0.63	0.09
TS, 1-min post-session	0.66 (0.83)	-1.99	3.31	0.79	0.22	1.00
HICT, 5-min post-session	-1.24 (0.62)	-3.22	0.73	-2.00	-0.42	1.00
TS, 5-min post-session	2.31 (0.83)	-0.34	4.96	2.78	0.78	0.18
TS, mid-session						
HICT, 1-min post-session	-3.29 (0.83)	-5.94	-0.64	-3.96	-1.11	0.003**
TS, 1-min post-session	-0.78 (0.63)	-2.79	1.23	-1.23	-0.26	1.00
HICT, 5-min post-session	-2.68 (0.83)	-5.33	-0.03	-3.23	-0.90	0.05
TS, 5-min post-session	0.87 (0.63)	-1.14	2.89	1.38	0.29	1.00
HICT, 1-min post-session						
TS, 1-min post-session	2.51 (0.83)	-0.14	5.16	3.02	0.85	0.09
HICT, 5-min post-session	0.61 (0.62)	-1.36	2.59	0.99	0.21	1.00
TS, 5-min post-session	4.16 (0.83)	1.51	6.82	5.01	1.40	<.001***
TS, 1-min post-session						
HICT, 5-min post-session	-1.90 (0.83)	-1.90	-4.55	-2.29	-0.64	0.67
TS, 5-min post-session	1.65 (0.63)	1.65	-0.36	2.61	0.56	0.28
HICT, 5-min post-session						
TS, 5-min post-session	3.55 (0.83)	0.90	6.20	4.28	1.20	0.001**

*$p<.05$
**$p<.01$
***$p<.001$

Supplementary Table 4-2 Post hoc Bonferroni comparisons for state anxiety scores

		95% CI for mean difference				
	Mean difference (standard error)	Lower	Upper	t	Cohen's d	p_{bonf}
HICT, 10-min pre-session						
TS, 10-min pre-session	-0.01 (0.14)	-0.42	0.41	-0.05	-0.02	1.00
HICT, mid-session	-0.10 (0.11)	-0.42	0.22	-0.91	-0.20	1.00
TS, mid-session	0.31 (0.14)	-0.11	0.72	2.21	0.61	0.44
HICT, 10-min post-session	0.08 (0.11)	-0.25	0.40	0.72	0.15	1.00
TS, post-session	0.39 (0.14)	-0.02	0.80	2.83	0.79	0.08
TS, 10-min pre-session						
HICT, mid-session	-0.09 (0.14)	-0.50	0.32	-0.65	-0.18	1.00
TS, mid-session	0.31 (0.11)	-0.01	0.63	2.92	0.63	0.06
HICT, 10-min post-session	0.08 (0.14)	-0.33	0.50	0.61	0.17	1.00
TS, 10-min post-session	0.39 (0.11)	0.08	0.72	3.73	0.80	0.01*
HICT, mid-session						
TS, mid-session	0.40 (0.14)	-0.01	0.82	2.92	0.81	0.06
HICT, 10-min post-session	0.17 (0.11)	-0.15	0.50	1.62	0.35	1.00
TS, 10-min post-session	0.49 (0.14)	0.07	0.90	3.54	0.98	0.01*
TS, mid-session						
HICT, 10-min post-session	-0.23 (0.14)	-0.64	0.19	-1.66	-0.46	1.00
TS, 10-min post-session	0.09 (0.11)	-0.24	0.41	0.08	0.17	1.00
HICT, 10-min post-session						
TS, post-session	0.31 (0.14)	-0.10	0.73	2.28	0.63	0.37

*p<.05
**p<.01
***p<.00

Chapter 5 Effects of circuit versus traditional strength training on physiological responses in women

Prelude

Chapter 4 found that in comparing the acute physiological and psychological responses to HICT and TS in trained women, HICT had greater BLA, HR, sRPE, and state anxiety compared to TS. These findings indicate higher cardiovascular load with HICT, likely due to the short rest periods and circuit setup in contrast to TS. Additionally, self-efficacy scores increased after both training conditions, which is important as self-efficacy is an important predictor of long-term exercise adherence. As a follow-up, the purpose of Chapter 5 was to determine the physiological responses to HICT versus TS in an 8-week study in trained women.

Section 1: Introduction

CT and TS are two dominant forms of resistance training using body weight, free weights, resistance bands, machines, or any combination thereof. CT involves repeating a sequence of exercises one after another with little to no rest between sets. In contrast, TS usually entails performing all sets of one exercise at a time with moderate to long rest periods between sets.

CT is a time-efficient way to improve muscle mass and strength as well as cardiorespiratory fitness [71, 75, 76]. However, CT is typically performed with low loads, not necessarily to failure, and is thus less effective for improving BMD and maximal strength compared to training at closer proximity to muscular failure [75-77]. HICT is a form of CT that involves training with higher loads closer to muscular failure and increases strength, lean mass, and BMD [88]. On the other hand, TS typically utilizes heavier loads with moderate to long rest periods between sets compared to CT [93]. TS significantly improves bone health [97, 127] as well as muscle mass [95, 198-200] and strength [78]. Some drawbacks to TS include the time required to complete a workout session, moderate cardiovascular health benefits compared to other forms of training (e.g., CT, aerobic training), and minimal body fat loss [79].

To date, there is limited research comparing the physiological effects of HICT compared to TS, and of the research that does exist, the vast majority is conducted in men. A 2011 study in trained men found that 8 weeks of HICT elicited similar gains in strength and muscle mass compared to TS [79]. To our knowledge, there are no studies specifically comparing HICT to TS in trained women, and the lack of research on this topic means that the existing findings in men cannot necessarily and confidently be applied to women.

Therefore, the purpose of this study was to determine the effects of HICT versus TS on strength, muscle girth, and body composition in trained women. It was hypothesized that HICT would not be significantly different from TS for increasing strength, muscle girth, and LBM, but would be more effective for decreasing body fat compared to TS, similarly to previous research in trained men [79].

Section 2: Methods

Experimental approach to the problem

To compare the effects of HICT versus TS on strength, muscle girth, and body composition in women, a longitudinal randomized parallel group trial was conducted. Participants were recruited using fliers posted across the California State University San Marcos campus and on various social media platforms. The independent variable was 'training condition' – namely, HICT or TS. Dependent variables included 3RM strength, muscle girth, skinfold thickness, and body composition.

Subjects

Due to the likelihood that logistics would constrain our sample size, rather than relying on an a priori sample size calculation, we recruited as many participants as we could between September 2022 and

February 2023. A total of 20 women volunteered for the study, and by the end, 14 participants completed the study (HICT = 7; TS = 7). Inclusion criteria were women between the ages of 18 and 40 years old, trained (≥6 months of resistance training experience), healthy, and free from musculoskeletal injury. Participants agreed not to take ergogenic aids, supplements, or medications that might affect resistance training performance. Participants were informed of the benefits and risks of the investigation prior to signing an informed consent form to participate in the study. Participant characteristics are summarized in Table 5-1. A minimum of 80% attendance was required for a participant to complete the study. One participant withdrew due to an injury sustained outside the research, three withdrew as a result of missing too many sessions, and two withdrew due to mild discomfort incurred during the training protocol which prevented participation at the required intensity and/or frequency. The methods and procedures used in this study were approved by Auckland University of Technology Ethics Committee, AUTEC Reference number 22/16. The study was also approved by the California State University San Marcos IRB #1925058-1.

Table 5-1 Participant characteristics at baseline (mean ± SD)

	HICT	TS
Age (years)	30.10 ± 4.65	26.94 ± 5.92
Height (cm)	160.34 ± 7.17	161.16 ± 5.27
Weight (kg)	66.74 ± 5.05	65.14 ± 16.40
Body fat percentage (%)	33.39 ± 7.28	34.50 ± 7.80
3RM leg press (kg)	112.75 ± 29.01	79.05 ± 42.30
3RM flat DB bench press (kg)	29.20 ± 5.82	25.30 ± 4.24
3RM trap bar deadlift (kg)	72.90 ± 15.24	65.12 ± 19.28
3RM lat pulldown (kg)	40.18 ± 5.34	37.58 ± 6.64
3RM hip thrust (kg)	113.07 ± 33.73	107.57 ± 16.87
3RM standing DB shoulder press (kg)	22.12 ± 3.36	19.12 ± 4.32

HICT n = 7; TS n = 7. No significant differences were found between groups for any variables ($p > 0.05$).

Procedures

During the pre-intervention phase, participants first took part in a familiarization session. Following a 5-minute treadmill walk at a brisk pace, they completed a dynamic warm-up consisting of the following exercises for 10 reps each: bent over thoracic spine rotation, body weight windmill, quad stretch to hamstring sweep, lateral squat, and dynamic shoulder circle. Next, they performed one set of each exercise (leg press, flat DB bench press, trap bar deadlift, lat pulldown, hip thrust, and standing DB shoulder press) at a 5-7 rating (0-10 Borg scale) of perceived exertion (RPE) within an 8 to 15 target rep range. The purpose of this phase was to ensure that the participants were familiar with the movements and allow the researcher to check the participants' exercise technique, making adjustments as needed. The second session, which took place 48-72 hours later, consisted of 3RM testing for each exercise. The third session consisted of the body composition assessment and took place 48-72 hours following the previous sessions. The participants were then randomly assigned to the HICT or TS group for the duration of the training intervention. Exercise descriptions were as follows:

Leg press: Sit down in the machine and position the feet on the foot pad roughly shoulder-width apart. Extend the legs until the knees lock out, then lower the load under control until the legs have reached roughly a 45-degree angle.

Flat DB bench press: Holding a DB in each hand, lie back on a flat bench. With the arms positioned on either side of the torso, press the DBs up until the elbows lock out, then lower under control.

Trap bar deadlift: Stand inside the trap bar and hold the handles with both hands. While maintaining a relatively neutral spine and a soft bend in the knees, pull the load off the floor by thinking of pushing into the ground. Extend the hips and stand tall, then reverse the motion and lower the load back to the floor under control.

Lat pulldown: Grab the bar with an approximately shoulder-width overhand grip. While maintaining torso upright, pull the elbows down towards the hips and bring the bar to the chest, then slowly return to the start position.

Hip thrust: Sit with a barbell across the hips and the upper back against a bench 12-14" in height. Push through the heels and extend the hips, keeping the head forward and chin tucked. Squeeze the glutes at the top of the repetition, then lower back down under control.

Standing DB shoulder press: Holding a DB in each hand by the shoulders, press the DBs overhead until the elbows lock out, then lower the DBs under control.

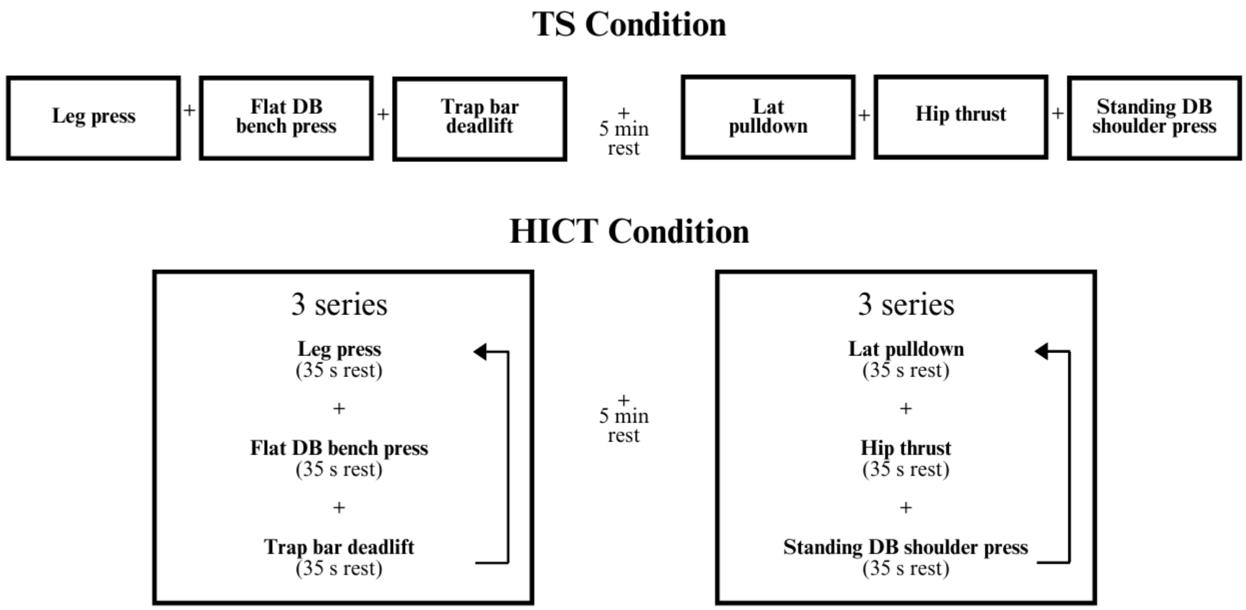
Training consisted of 3 weekly sessions performed on non-consecutive days for a total of 8 weeks. Initial loads started at approximately 65% of their 3RM, rounded down to the nearest 1.25 kilograms (kg). From there, participants performed sets consisting of 8 to 15 repetitions at an 8 or 9 on the Borg CR10 RPE scale. Loads were increased or decreased in subsequent sets as needed to maintain the appropriate perceived exertion (RPE 8-9) and target repetition range (8-15 per set).

The HICT group completed exercises "vertically" (one set completed per exercise before moving onto the next exercise) in two separate 3-exercise series or circuits, with 35 seconds of rest between sets (enough time to transition safely between exercises) and a 5-minute break between each series. Participants would move from one exercise to the next (e.g. one set of leg press, then one set of flat DB bench press, then one set of trap bar deadlift), repeating the series until 3 sets of each exercise had been completed. The first circuit consisted of leg press, flat DB bench press, and trap bar deadlift; the second circuit consisted of lat pulldown, hip thrust, and standing DB shoulder press.

Meanwhile, the TS group completed all sets of one exercise at a time, resting 3 minutes between sets, before moving onto the next exercise, with up to a 5-minute break after the first 3 exercises. In other words, those in the TS group would complete the first set of leg press, rest 3 minutes, then a second set of leg press, rest 3 minutes, and then a final set of leg press before moving onto the second exercise, the flat DB bench press, and so on.

Thus, both groups completed the same exercises for the same repetition range and number of sets, and they differed only in the order in which the exercises were executed as well as the rest taken between sets. The warm-up, RPE, and rep ranges were the same between groups. Participants were supervised by at least one experienced trainer at every session to ensure exercise technique met the required range of motion standards, each set was terminated close to failure, and rest periods were strictly enforced. See Figure 5-1.

Figure 5-1 HICT and TS protocols



TS performed 3 sets of each exercise one at a time with a 3-minute rest between sets, and a 5-minute rest allowed after the 3rd exercise; HICT performed 3 series of 2 circuits with a 5-minute rest.

Participants were asked to maintain their usual eating habits and to not ingest any supplements that may affect their training performance. Participants were required to attend a minimum of 20 of the 24 training sessions to complete the study.

Strength: 3RM strength of each exercise was tested prior to beginning and after completion of the training protocol. These testing sessions were not included in the 24 training sessions. Following a 5-minute steady-state cardiovascular warm-up consisting of brisk walking on a treadmill and the 5-minute dynamic warm-up described in the first paragraph of the procedures, participants completed 2 sets of 5-8 repetitions of each exercise at a submaximal load with 2 minutes of rest between sets. Then, an initial load was lifted for 3 reps that was within an estimated 50-70% of the participants' capacity. Selection of this load was informed by prior experience of the participant and gauged by the investigator who is an experienced trainer. After a load was successfully lifted, the participants were allowed to rest 3-5 minutes before attempting another lift with additional load increased by 1.25 to 20kg (depending on participant strength and the difficulty of the prior set) for 3 repetitions. Participants were allowed up to 5 total 3RM attempts. If the final attempt was 1-2 repetitions, this load was used to calculate their 3RM using the NSCA Training Load Chart [201].

Muscle girth and skinfold thickness: Girth and skinfold measurements were performed on the right limbs at the midpoint between the humeral greater tuberosity and lateral epicondyle for the arm and the midpoint between the greater trochanter and lateral epicondyle of the femur for the leg. Muscle girth measurements were obtained with a steel tape measure, and skinfold measurements were performed in a rotational order using a metal skinfold caliper (Lange, Santa Cruz, CA) at the same sites. All measurements were performed by the same researcher in triplicate to eliminate inter-rater variability. The mean of the two closest values was recorded for each site. Measurements were taken at pre- and post-intervention.

Body composition: Height was measured using a stadiometer, and body mass was measured using a balance beam scale (Health-o-Meter; Creative Health Products, Ann Arbor, MI). Participants had their body composition measured via dual-energy x-ray absorptiometry (DXA, Lunar Prodigy, GE Corp, Madison, WI) pre- and post-intervention at the Cal State University San Marcos kinesiology lab. The DXA coefficient of variation in the Cal State University San Marcos kinesiology lab is 0.8-5.9%, and intraclass correlation (ICC) reliability is 0.996 for percent body fat, 0.975 for fat mass (FM), and 0.994 for fat-free mass [202]. Body composition measurements were conducted by the same technician using the lab's established protocols for best and standardized practice. Participants were asked to refrain from alcohol, caffeine, and moderate/vigorous exercise for at least 14 hours before each visit and to abstain from food 12 hours before testing. Even so, not all participants were able to adhere fully to the standardized conditions (namely, abstaining from food 12 hours before testing), and timing was not always consistent between pre- and post-intervention assessments due to scheduling logistics. While the data of these participants could have been excluded, doing so would have yielded an even smaller sample size, so the decision was made to retain data even when standardization was not perfectly followed, and to acknowledge this limitation. enCore version 17 (GE Corporation, Madison, WI, USA) was used to calculate percent body fat, FM, and LBM. Software further differentiated bone mass from lean mass.

Statistical analyses

All data are reported as means ± standard deviations. A two-way ANOVA with repeated measures (group x time) was used to compare differences in pre- and post-intervention 3RM strength, LBM, and body composition between groups. Effect size statistics were used to determine the magnitude of differences within and between the two groups, and were defined as small, medium, and large represented by Cohen's d of greater than 0.2, 0.5, and 0.8, respectively. Confidence intervals (95% CI) were presented where appropriate. Significance was accepted when $p < 0.05$. All analyses were completed using JASP (v 0.17.2.1).

Section 3: Results

The study was based on 14 participants who responded to the study invitation and completed the study with a minimum attendance of 80%. At the end of the study, the number of participants in each group were as follows: HICT, $n = 7$; TS, $n = 7$. Out of a total of 24 sessions, attendance was 21.00 ± 1.41 for HICT and 21.14 ± 1.46 for TS, with no significant difference in attendance between groups ($p = 0.86$). The average number of repetitions performed per set throughout the training intervention was 9.97 ± 0.56 for HICT and 9.45 ± 0.97 for TS, with no significant difference between groups ($p = 0.24$).

Pre-training characteristics of subjects in each training group are presented in Table 5-1. No significant pre-intervention differences in any participant characteristics or 3RM strength measures were found between HICT and TS. Average loads for all exercises and total volume between groups are displayed in Tables 5-2 and 5-3, respectively.

Table 5-2 Average load for each exercise throughout training intervention

Exercise (kg)	HICT	TS	% difference	Effect size (Cohen's d)	95% CI for group Lower	95% CI for group Upper
Leg press	89.61 ± 23.65	83.94 ± 35.79	-6.33	0.19	-0.87	1.23
Flat DB bench press	25.70 ± 4.90	24.15 ± 3.54	-6.03	0.36	-0.70	1.41
Trap bar deadlift	61.60 ± 8.50	63.54 ± 14.20	3.15	-0.16	-1.21	0.89
Lat pulldown	32.45 ± 4.28	33.12 ± 4.63	2.06	-0.15	-1.20	0.90
Hip thrust	88.4 ± 17.86	93.16 ± 13.52	5.38	-0.30	-1.35	0.76
Standing DB shoulder press	16.69 ± 3.30	17.36 ± 3.07	4.01	-0.21	-1.26	0.84

No significant differences were found between groups for any variables ($p > 0.05$).

Table 5-3 Training volume for each exercise throughout training intervention

Exercise (kg)	HICT	TS	% difference	Effect size (Cohen's d)	95% CI for group Lower	95% CI for group Upper
Leg press	59,780.51 ± 15,539.95	53,642.11 ± 25,640.36	10.27	0.29	-0.77	1.34
Flat DB bench press	16,773.51 ± 5,099.25	14,359.69 ± 2,178.05	14.39	0.62	-0.47	1.68
Trap bar deadlift	33,666.89 ± 14,576.81	35,454.63 ± 7,907.59	-5.31	-0.15	-1.20	0.90
Lat pulldown	19,681.35 ± 3,150.00	19,419.05 ± 2,519.26	1.33	0.09	-0.96	1.14
Hip thrust	55,642.13 ± 13,585.51	57,206.70 ± 8,965.06	-2.81	-0.14	-1.18	0.92
Standing DB shoulder press	9,983.66 ± 2,075.51	9,862.75 ± 1,585.28	1.21	0.07	-0.98	1.11
Total	195,528.06 ± 37,670.88	189,944.92 ± 43,549.06	2.86	0.14	-0.91	1.18

No significant differences were found between groups for any variables ($p > .05$).

Strength

The results of all strength changes pre- and post-intervention are displayed in Table 5-4. A statistically significant main effect of time indicated an increase in strength for every exercise ($p < 0.001$; $84.97 \geq F \leq 232.83$); however, the main effects for group and interactions for all exercises were not statistically significant.

Table 5-4 3RM strength

Exercise (kg)	Pre-intervention	Post-intervention	% change	Effect size (Cohen's d)	*p**	*F**
Leg press						
HICT	112.75 ± 29.01	189.53 ± 22.49†	68.10	2.96	0.18	1.99
TS	79.05 ± 42.30	163.94 ± 58.63†	107.39	1.66		
Flat DB bench press						
HICT	29.20 ± 5.82	35.58 ± 6.06†	21.85	1.07	0.31	1.12
TS	25.30 ± 4.24	33.70 ± 4.90†	33.20	1.83		
Trap bar deadlift						
HICT	72.90 ± 15.24	94.28 ± 12.69†	29.33	1.52	0.56	0.37
TS	65.12 ± 19.28	90.72 ± 22.49†	39.31	1.22		
Lat pulldown						
HICT	40.18 ± 5.34	51.70 ± 8.30†	28.67	1.65	0.66	0.29
TS	37.58 ± 6.64	51.06 ± 7.26†	35.87	1.94		
Hip thrust						
HICT	113.07 ± 33.75	154.54 ± 25.37†	36.68	1.39	0.26	1.39
TS	107.57 ± 16.87	157.46 ± 18.51†	46.38	2.82		

Standing DB shoulder press						
HICT	22.12 ± 3.36	26.84 ± 3.26†	21.34	1.43	0.08	3.68
TS	19.02 ± 4.32	25.34 ± 3.60†	33.23	1.56		

*values for group x time interaction
†significantly different from pre-intervention

Muscle girth and skinfold thickness

Muscle girth and skinfold thickness results are displayed in Table 5-5. There were no statistically significant main effects of time ($0.31 \geq p \leq 0.52$; $0.43 \geq F \leq 0.97$), group ($0.21 \geq p \leq 0.88$; $0.03 \geq F \leq 1.75$), or interactions ($0.30 \geq p \leq 0.70$; $0.15 \geq F \leq 1.16$) for any sites examined.

Table 5-5 Muscle girths and skinfold thicknesses.

	Pre-intervention	Post-intervention	% change	Effect size (Cohen's d)	95% CI for group	*p**	*F**
Girth – Right Arm (cm)							
HICT	26.68 ± 4.14	26.08 ± 2.90	-2.25	0.17	-1.07 to 1.34	0.36	0.92
TS	26.08 ± 3.93	26.05 ± 3.99	-0.12	0.01			
Girth – Right Leg (cm)							
HICT	56.26 ± 5.01	54.61 ± 3.70	-2.93	0.37	-0.95 to 1.28	0.35	0.94
TS	54.27 ± 6.14	54.67 ± 7.83	0.74	0.06			
Skinfold – Right Arm (mm)							
HICT	22.43 ± 3.92	22.84 ± 5.00	1.83	0.09	-0.87 to 1.42	0.70	0.16
TS	20.36 ± 7.70	21.36 ± 8.43	4.91	0.12			
Skinfold – Right Leg (mm)							
HICT	29.71 ± 5.58	28.89 ± 5.04	-2.76	0.15	-0.49 to 1.88	0.70	0.15
TS	25.14 ± 7.39	24.79 ± 6.70	-1.39	0.05			

*values for group x time interaction

Body composition

Body composition results are displayed in Table 5-6. There were no statistically significant (p = 0.84, F = 0.04) main effects of time, group (p = 0.82, F = 0.05), or interactions (p = 0.70, F = 0.16) for body mass. There was a statistically significant main effect of time (p = 0.04, F = 5.33) indicating a decrease in body fat percentage; however, the main effect for group (p = 0.75, F = 0.11) and interaction was not statistically significant (p = 0.53, F = 0.41). There was a statistically significant main effect (p = 0.01, F = 9.23) of time indicating an increase in LBM; however, the main effect for group (p = 0.66, F = 0.29) and interaction were not statistically significant (p = 0.60, F = 0.34). There were no statistically significant main effects of time (p = 0.42, F = 0.69), group (p = 0.96, F = 0.00), or interactions (p = 0.40, F = 0.78) for FM. There were no statistically significant main effects of time (0.23≥p≤0.95; 0.14≥F≤0.88), group (0.23≥p≤0.85; 0.04≥F≤1.54), or interactions (0.32≥p≤0.80; 0.07≥F≤1.07) for arm, leg, and trunk LBM; similarly, there were no statistically significant main effects of time (0.14≥p≤0.88; 0.03≥F≤2,54, group (0.64≥p≤0.86; 0.03≥F≤0.23), or interactions (0.50≥p≤0.94; 0.01≥F≤0.47) for arm, leg, and trunk FM. Individual changes in LBM and FM for HICT and TS are displayed in Figures 5-2 and 5-3, respectively.

Table 5-5 Body composition

Exercise (kg)	Pre-intervention	Post-intervention	% change	Effect size (Cohen's d)	*p**	*F**
Body mass (kg)						
HICT	66.74 ± 5.05	66.68 ± 5.44	-0.09	0.01	0.70	0.16
TS	65.14 ± 16.40	65.31 ± 15.96	0.26	0.01		
Body fat (%)						
HICT	33.39 ± 7.28	32.40 ± 6.75	-2.96	0.14	0.53	0.41
TS	34.50 ± 7.80	33.94 ± 8.57	1.56	0.07		
LBM total (kg)						
HICT	41.12 ± 4.64	42.03 ± 4.25	2.21	0.20	0.57	0.34
TS	39.85 ± 5.77	40.47 ± 4.85	1.56	0.12		
LBM arms (kg)						
HICT	4.06 ± 0.58	4.04 ± 0.58	-0.49	0.03	0.80	.07
TS	3.74 ± 0.75	3.78 ± 0.53	1.07	0.06		
LBM legs (kg)						
HICT	14.60 ± 1.66	15.09 ± 1.57	3.36	0.30	0.32	1.07
TS	13.66 ± 2.31	13.10 ± 3.55	-4.10	0.19		
LBM legs (kg)						
HICT	14.60 ± 1.66	15.09 ± 1.57	3.36	0.30	0.32	1.07
TS	13.66 ± 2.31	13.10 ± 3.55	-4.10	0.19		
LBM trunk (kg)						
HICT	19.65 ± 2.65	20.08 ± 2.62	2.19	0.17	0.60	0.28
TS	19.49 ± 3.29	19.67 ± 2.52	0.92	0.06		

FM total (kg)						
HICT	22.98 ± 5.14	22.58 ± 5.34	-1.74	0.08	0.40	0.78
TS	22.55 ± 11.21	22.56 ± 11.55	0.04	<0.001		
FM arms (kg)						
HICT	2.27 ± 0.35	2.16 ± 0.49	-4.85	0.26	0.94	0.01
TS	2.14 ± 0.59	2.02 ± 0.72	-5.61	0.18		
FM legs (kg)						
HICT	8.76 ± 1.54	8.64 ± 1.74	-1.37	0.07	0.59	0.31
TS	8.01 ± 3.63	8.04 ± 4.01	0.37	0.01		
FM trunk (kg)						
HICT	11.16 ± 3.96	10.97 ± 3.98	-1.70	0.05	0.50	0.47
TS	11.56 ± 7.28	11.67 ± 7.15	0.95	0.02		

*values for group x time interaction
†significantly different from pre-intervention

Figure 5-2 Individual changes in LBM and FM in HICT group

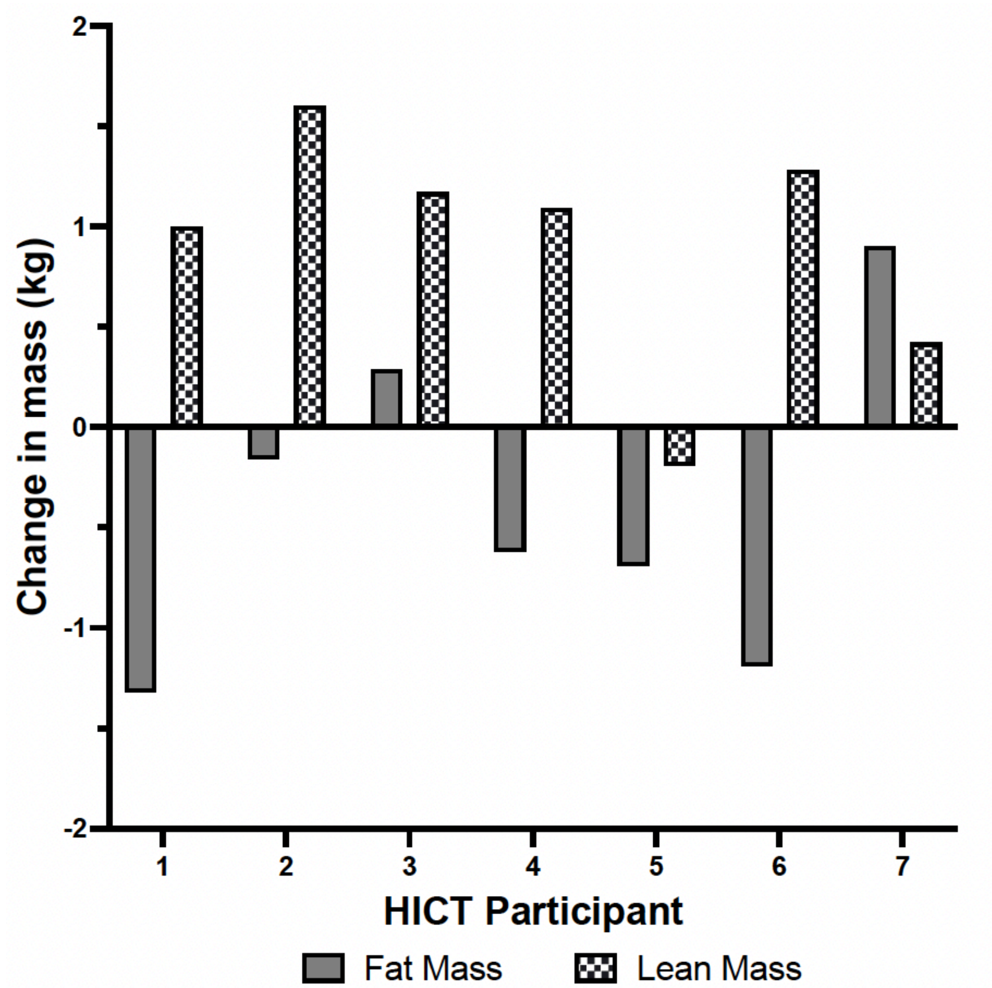
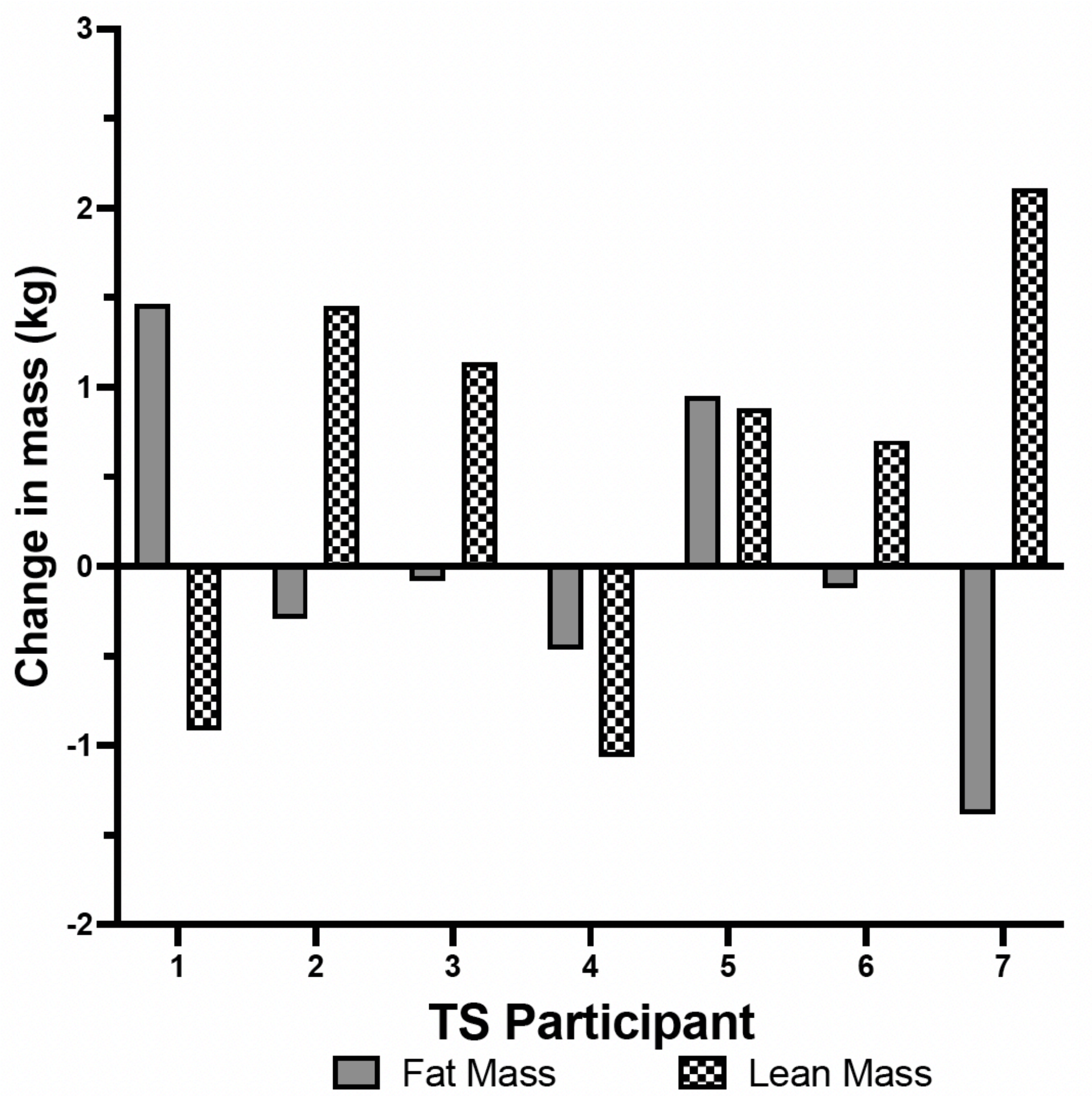


Figure 5-3 Individual changes in LBM and FM in TS group



Section 4: Discussion

To the authors' knowledge, this was the first study to investigate the physiological effects of HICT vs. TS in trained women. The primary finding was that both HICT and TS yielded similar increases in strength and LBM and a decrease in body fat percentage, with no statistically significant change in muscle girth, skinfold thickness, body mass, or FM. The hypothesis that HICT's impact on strength, muscle girth, and LBM would not significantly differ from TS's was supported, but the hypothesis that only HICT would experience a reduction in body fat percentage was not.

With regards to the changes in LBM and FM, individual data displayed in Figures 5-2 and 5-3 indicate that several participants experienced noteworthy increases in LBM and decreases in FM. Specifically, 4 HICT participants gained 1kg or more LBM, and 3 TS participants gained 1kg or more LBM, with one TS participant gaining 1.45kg LBM and losing 0.29kg FM, and another TS participant gaining 2.11kg and dropping 1.35kg FM. A total of 8 out of the 14 total participants experienced simultaneous muscle gain and fat loss, a relatively common phenomenon known as body recomposition [107]. This is especially marked given these changes occurred within 8 weeks in the absence of any dietary intervention.

Our results demonstrate that even when rest periods are shorter, as in the HICT group, similar strength and LBM gains can be achieved as long as sets are terminated close to muscular failure. This outcome may also be due in part to the exercise order in the HICT group, as rather than straight sets, the circuit nature allowed the specific muscles which were trained on a given exercise to rest during subsequent exercises which trained different musculature.

Further, our results corroborate the findings of Brentano et al. [75] which found no significant differences in isometric strength, upper limb dynamic strength, and lower limb dynamic strength between CT and TS after 24 weeks of training in untrained postmenopausal women with bone loss. It should be noted that in that particular study, those in the CT group trained at lower intensities, thus their style of training could not be classified as HICT, yet strength increases were still observed.

To the authors' knowledge, there are three prior studies to date specifically examining HICT in women. Two studies found that HICT significantly decreased body fat percentage while increasing strength [84, 85], while one found that HICT improved strength but did not change body composition [203]. However, in all of these studies, the exercises performed by participants in the HICT condition consisted primarily of body weight exercises (e.g. jumping jacks, sit-ups, squats, planks) rather than externally loaded gym-based lifts. While working sets were completed with high perceived exertion in these studies, unlike in the present study, it was not also specified that they were terminated close to muscular failure, and no prior study directly compared HICT to TS. Still, these findings suggest that it is possible for HICT to significantly increase strength and possibly reduce body fat percentage even while not pushing close to muscular failure and without using external resistance.

Similar to our findings, Alcaraz et al. [78] found that HICT was equally as effective at TS in improving bench press and half squat 1RM after 8 weeks of training in trained men. The HICT group significantly decreased their body fat percentage by 1.5% while the TS group experienced a non-significant decrease of 1.1%, and both groups significantly increased LBM. Further, Paoli and colleagues found that HICT was more effective than low-intensity CT and endurance training in reducing body mass, FM, and increasing strength in overweight middle-aged men [77].

Previous research examining CT at lower loads not close to muscular failure in comparison to TS reported superior results following TS for strength and muscle mass increases [204]. Additionally, the strength and LBM gains occurred in trained individuals with a consistent history of lifting weights, in whom additional gains can be slower [205]. Thus, the ability of HICT to improve strength and muscle mass in those with training experience is noteworthy for populations seeking a more time-efficient way to exercise. With standardized rest periods making up the majority of the time spent in each session, we had an average completion duration of 50 to 60 minutes in HICT and 75 to 85 minutes in TS. Thus, HICT was able to complete the same amount of work in less time, meaning the training density of HICT was much greater, with a higher work:rest ratio. However, higher and lower work:rest ratios will likely be perceived differently. Thus, future research should compare perceived exertion, enjoyment, and perceived difficulty between HICT and TS to better ascertain which modality an individual should employ.

There are other time-saving strategies available for those seeking strength and body composition alterations besides CT. Specifically, antagonist paired sets, in which exercises that train opposing muscle groups are paired together, which help reduce training time without compromising training volume and is equally as effective at TS at increasing 1RM strength [206, 207]. Other advanced time-saving strategies which seem not to compromise adaptation include drop-set training, in which a traditional set is performed, then immediately followed by another set (or multiple sets) with reduced load [208]; and the rest-pause method, in which sets are broken up into smaller sets with short breaks in between, thus allowing for maintenance of high loads [209].

Caution should be taken when interpretating the body composition results of this study. Although participants were asked not to make any dietary changes throughout the duration of the training intervention, their diets were not standardized, nor were specific dietary strategies recommended. Rather, pre-intervention 24-hour food recalls were collected to increase dietary control by raising awareness of participants' diets and to encourage them to be consistent with their diets throughout the study. However, no mid- or post-intervention diet log was collected, thus there was no way to confirm whether or not participants maintained the same diets throughout. Future research should either closely monitor dietary intake or examine the effects of dietary interventions implemented concurrently alongside the training interventions to better understand the impact of diet on the outcome variables. Even so, the findings from this study are meaningful in that both HICT and TS observed significant physiological changes despite not controlling for diet, suggesting that either modality is effective for increasing strength and LBM in trained women.

Several other limitations arose during the data collection process that must be addressed. Of primary concern was the small sample size. Given the total number of visits required to participate in the study, participant interest and availability was limited. Further, scheduling obstacles meant that body composition testing conditions pre- and post-intervention were not fully standardized for all participants. Specifically, five participants did not remain fasted in the 12 hours leading up to their DXA scans, and the timing of their assessments were not consistent from pre- to post-intervention (i.e., some individuals had their assessments in the morning pre-intervention but late afternoon post-intervention, or vice versa) due to scheduling logistics. Thus, their body composition results may have contained additional error. Finally, caution should be taken when extrapolating the findings of this study to a training plan of longer duration or to men, individuals in different age groups, those with different levels of training experience, or those performing a program with different training variables.

Section 5: Practical applications

The results of this study suggest that both HICT and TS are viable methods to induce strength and LBM increases and decrease body fat percentage in trained women provided sets are terminated close to failure. The HICT sessions took less time to complete, thus those looking to be more time-efficient while still achieving strength and LBM increases may find HICT useful. When deciding whether to adopt HICT, TS, or a combination of both training styles, personal preference, the ability to sustain a higher work:rest ratio and time constraints can be used as guiding factors due to both training styles resulting in increased strength and LBM and decreased body fat percentage.

Chapter 6 Effects of circuit and traditional strength training on psychological measures in women: a qualitative analysis

Prelude

The findings of Chapter 5 revealed that HICT and TS were equally effective in increasing strength and LBM and decreasing body fat in trained women when sets were terminated closer to failure. Additionally, HICT was able to complete the same amount of work in less time and thus had higher training density compared to TS. Next, the purpose of Chapter 6 was to determine how HICT and TS impacted psychological measures in women.

Section 1: Introduction

Resistance training involves progressively improving the body's ability to resist force through external resistance including DBs and barbells, machines, resistance bands, or bodyweight exercises [3]. In addition to increasing strength and muscle mass, resistance training can result in multiple physical health benefits such as a reduction in risks and symptoms of osteoporosis, arthritis, diabetes, and obesity as well as mental health benefits such as reduced anxiety and depression [210, 211]. Further, resistance training can improve cardiovascular health, resting blood pressure, blood lipid profiles, BMD, and more [135, 210].

The ACSM recommends adults resistance train two or three days per week [35]; the NSCA similarly recommends a minimum of two days per week [9]. Unfortunately, participation rates amongst adults in the United States have remained low at 22.8%, though this number has trended upward in the past two decades [36, 37]. Specifically, 25.8% of female adults meet the resistance training recommendations compared to 34.8% of males in the US [8], and similarly higher participation rates in males versus females are seen in other countries including Brazil, Canada, England, and South Korea [212].

These low participation rates are a concern as regular resistance training can counteract and reverse many health problems such as age-related muscle and strength loss (sarcopenia) and associated bone loss [112], fat gain [135], metabolic syndrome [5], and more [6]. With muscle mass loss occurring at a rate between 3% - 8% each decade after age 30 [133] and increasing to 5 - 10% each decade after fifty [134], this is a concern as this can negatively impact ADL and lead to functional impairment and disability, which lead to decreased quality of life [213-215]. For these reasons, a better understanding of adults' perceptions and experiences of different forms of resistance training are crucial to inform strategies to enhance adherence.

HICT is a form of CT in which a sequence of exercises is performed one after another with little to no rest between sets. Movements are performed with higher loads and pushed closer to muscular failure compared to standard CT [88]. The high intensity nature of HICT increases strength, lean mass, and BMD to a similar degree to TS compared to standard CT [79]. In contrast, TS entails performing one exercise at a time, utilizing heavier loads with moderate to long rest periods between sets [93] and can improve strength [78, 88, 212], muscle mass [95], and bone health [127, 212]. From a practical perspective, HICT is more time efficient but often requires utilizing multiple pieces of exercise equipment at once (depending on the exercises performed, e.g., lat pulldown followed by barbell hip thrust followed by standing shoulder press), whereas TS requires more time to complete an exercise session but only requires one exercise machine at a time. TS also offers more modest cardiovascular health benefits compared to HICT and aerobic exercise [79], which provide a more robust cardiorespiratory stimulus, and therefore may also be perceived as more demanding.

There a small number of qualitative studies examining resistance training in women. A recent qualitative study exploring women's experiences with resistance training identified five themes linking resistance training with mental health and well-being: self-acceptance, personal growth, flow state, social affiliation, and autonomy [152]. Some participants found their resistance training sessions to be a vehicle to relief stress and frustration, and their narrative expressed a sense of enjoyment, increased confidence, and improved psychological function. These findings aligns with previous research which highlighted the role of resistance training in improving wellbeing and positive body image [151]. Other qualitative studies have found that resistance training was commonly perceived as a gendered activity – in other words, the weights section of the gym is oftentimes viewed as being for men and not for women – thus normalizing the gender differences in the gym [51, 216].

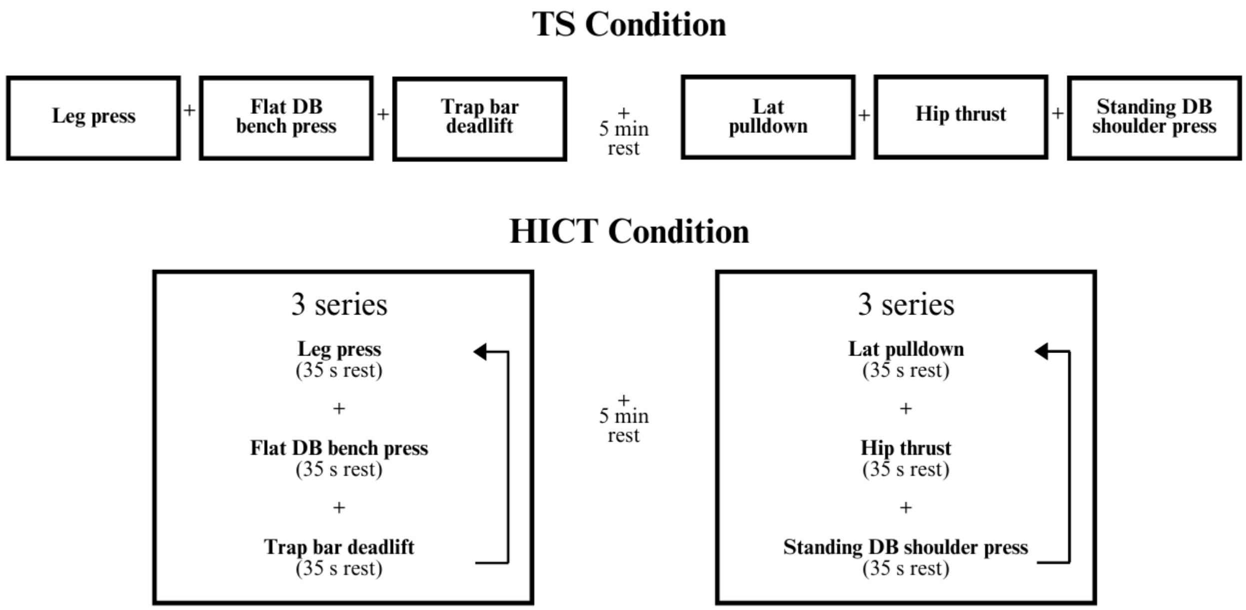
To the authors' knowledge, there is no research to date exploring the qualitative psychological experiences of HICT and TS in women. The dearth of research in this area means that little is known about how HICT and TS impact women psychologically, and thus our understanding in this area is limited. Therefore, the purpose of this study was to utilize in-depth surveys to understand the impact of HICT and TS on women's perceptions, experiences, motivations, and apprehensions regarding resistance training. These qualitative experiences following both HICT and TS will provide a better understanding of the experiences of women regarding their perceptions of body image, quality life, motivation to continue exercising, and apprehensions regarding resistance training to inform future research, help practitioners with exercise program design and implementation with clients, and complement existing quantitative comparisons of such training modalities.

Section 2: Methods

Experimental approach to the problem

A longitudinal parallel group trial was conducted to explore the effects of HICT and TS for various quantitative psychological and physiological outcomes of relevance (Figure 6-1). The present qualitative analysis was a part of the larger trial and was designed to provide a more complete understanding of the qualitative experiences of the participants to complement the long-term physiological comparisons. Participants were recruited from fliers posted across the California State University San Marcos campus and on various social media platforms. To catalogue their experiences, participants completed qualitative written interviews which prompted them to reflect on their exercise history, expectations, apprehensions, and perceptions of self, prior to beginning and midway through the interventions. Upon completion of HICT or TS, the participants were then asked to reflect on their outcomes and future plans.

Figure 6-1 HICT and TS protocols



TS condition performed 3 sets of each exercise with a 3-minute rest between sets and a 5-minute rest allowed after the third exercise. HICT condition performed 3 series of 2 circuits with a 5-minute rest in between.

Subjects

A total of 20 women volunteered for the study, and by the end, 14 completed the study (HICT = 7; TS = 7). Inclusion criteria were trained (≥6 months of resistance training experience), healthy women between the ages of 18 and 40 years, free from musculoskeletal injury. Participants agreed not to take ergogenic aids, supplements, or medications that might affect resistance training performance. Participants were informed of the benefits and risks of the investigation prior to signing an informed consent form to participate in the study. Participant characteristics are summarized in Table 6-1. A minimum of 80% attendance was required for a participant to complete the study. One participant withdrew due to an injury sustained outside the research, three withdrew due to missing too many sessions, and two withdrew due to mild pain incurred during the training protocol which prevented participation at the required intensity and/or frequency. The methods and procedures used in this study were approved by Auckland University of Technology on 22 March 2022, 22/16. The study was also approved by the California State University San Marcos IRB on 22 June 2022.

Qualitative questionnaires: To explore the participants' subjective experiences of resistance training, questionnaires were administered to each participant at three stages: within one week pre-intervention, mid-intervention, and within one week post-intervention. Participants were asked for written accounts of their feelings, attitudes, actions, intentions, and opinions on various topics pertaining to the exercise experience in general (Table 6-2), based heavily on the questions asked in a similar study [61].

Table 6-1 Participant characteristics at baseline (mean ± SD)

	HICT	TS
Age (years)	30.10 ± 4.65	26.94 ± 5.92
Height (cm)	160.34 ± 7.17	161.16 ± 5.27
Weight (kg)	66.74 ± 5.05	65.14 ± 16.40
Body fat percentage (%)	33.39 ± 7.28	34.50 ± 7.80
3RM leg press (kg)	112.75 ± 29.01	79.05 ± 42.30
3RM flat DB bench press (kg)	29.20 ± 5.82	25.30 ± 4.24
3RM trap bar deadlift (kg)	72.90 ± 15.24	65.12 ± 19.28
3RM lat pulldown (kg)	40.18 ± 5.34	37.58 ± 6.64
3RM hip thrust (kg)	113.07 ± 33.73	107.57 ± 16.87
3RM standing DB shoulder press (kg)	22.12 ± 3.36	19.12 ± 4.32

HICT $n = 7$; TS $n = 7$. No significant differences were found between groups for any variables ($p > 0.05$).

Table 6-2 Questionnaire topics and questions

Topic	Questions
	Pre-Intervention Questionnaire
Exercise history	Can you tell me about your past experience with exercise? How long ago and how did you get started with resistance training? What knowledge do you have of resistance training?
Expectations and initial opinions	What are you expecting to gain physically and mentally from this resistance training interventions? What are your opinions about women and resistance training?
Apprehensions	What concerns or anxieties (if any) do you have about resistance training?
Self-perceptions	How do you perceive your physical and psychological health? What does mental health mean to you, and how do you perceive your quality of life? What does quality life mean to you, and how do you describe your quality of life? What feelings do you associate with your body?
	Mid-Intervention Questionnaire
Current experiences	Describe your experience so far with the program. How does it feel when exercising? How does it feel immediately before the session? What about after the session?
Perceived changes	Have you experienced any positive changes in your physical or mental health associated with the program? What about negative changes? How do these changes relate to your quality of life?
Apprehensions	Have any apprehensions you may have had subsided? What have you learned so far about resistance training? Have any different concerns emerged?
Self-perceptions	How would you best describe yourself? How do you perceive your physical and psychological health? How do you perceive your quality of life? What feelings do you associate with your body?

	Post-Intervention Questionnaire
Outcomes	What did you gain from this experience, psychologically? How do these relate to your physical benefits? How do the outcomes relate to your quality of life and activities of daily living?
Meeting needs	Were your expectations of the program met? How do you think resistance training can affect women in general? Would you recommend this type of exercise intervention to other women? Why or why not?
Apprehensions	Were any apprehensions you may have had resolved? What have you learned about resistance training?
Self-perceptions	How would you best describe yourself? How do you perceive your physical health? Psychological health? Quality of life? What feelings do you associate with your body?
Plans	Do you anticipate continuing resistance training? On your own, with a friend, or with a qualified professional?
Other	Is there anything else you would like me to know about your experiences in resistance training?

Data analysis

To analyze the data, a qualitative descriptive analysis was conducted in order to assess the *who*, *what*, and *where* of participants' experiences [217]. Qualitative description (QD) is a pragmatic approach that allows researchers to remain close to their data as well as the words utilized by participants and is considered the preferred method of choice for straight descriptions of phenomena [218]. Descriptive statistics are often included to describe the study sample, and techniques from other qualitative traditions are frequently adopted and combined to yield rich data [219]. The goal of QD is to understand the latent variable, which is helpful for concept clarification and instrument development [217]. In contrast with other qualitative approaches, QD is less theory-driven which leaves room to not be committed to a specific theory or framework [220].

All data were divided into two groups: a) TS = 7; b) HICT = 7. The analysis of the data first involved reading through all survey responses multiple times and making notes of key words and phrases. Next, the first author (SLC) broke the data down into codes from the notes and observations, then arranged them into themes. Similar phrases and patterns were identified, and commonalities and differences were extracted from the data for further consideration. Eventually, generalizations were decided upon that accurately reflected the data. Meaningful quotations from each were highlighted and presented, with participants' ID numbers from the study included to easily attribute quotes to specific participants without revealing their identity. During manuscript preparation, the first author's (SLC) initial coding of participant responses was cross-checked by the second author (ERH) to identify any interpretation disagreements, which were then resolved via discussion, resulting in minor modifications to the manuscript.

Section 3: Results

The results of the pre-, mid-, and post-intervention surveys were divided into four themes which were generated from the data. The findings are presented below.

Theme 1: Apprehensions

This theme covered the concerns participants had about taking part in the training study and how these concerns changed or were resolved over the course of the study. Prior to the intervention, many participants reported concerns about injuries and perceived lack of time. After starting the intervention, participants reported that the supervised nature of the exercise sessions alleviated their concerns about injury. Additionally, participants reported that they were indeed in "good hands" and that they could put in significant effort without worrying about injury. Participants were also concerned about the time commitment prior to starting the study; however, they explained that the accountability was helpful for them, and attending these sessions boosted their confidence in being able to complete an exercise program. Thus, supervised resistance training programs appear to be helpful in ensuring workout consistency, and this supervision was instrumental to the participants' success.

"I am a little nervous about injury." When asked about any concerns or apprehensions participants had prior to beginning the intervention, some expressed worries about their technique on exercises and whether or not they would get injured during the intervention. This was articulated in remarks such as, "*I have some injuries to my left arm and right leg [from before the study] and am worried about my imbalances*," (AA01, HICT), "*I am a little nervous about injury, but I also trust that I'm in good hands*," (AZ31, HICT), and "*[My apprehensions are] getting injured [and] incorrect form.*" (CC38, TS)

However, four weeks into the study, there was already a marked sense of relief, with one participating noticing that "*I am so happy I can lift heavy while being supervised for my form*" (AZ31, HICT).

By the end of the study, all participants who had expressed concerns about this at the outset felt more enthusiastic and confident about their ability to exercise without getting hurt.

"*I am more eager to exercise than ever, because I know I can do it correctly and continue to push harder every session. I am feeling so much stronger. I recover quicker and feel less soreness. I am having fewer issues with my left arm as well*." (AA01, HICT)

Further, the support provided by the study staff helped overcome these apprehensions.

"*When I had any physical discomfort while training, my concerns were immediately addressed and cues given helped me do movements that were aligned properly and didn't cause pain. Injuring myself was my only concern*." (AZ31, HICT)

Time availability. Another commonly cited apprehension was time availability. Specifically, many participants were concerned about the long commute to and from the training facility as well as fitting in the exercise sessions with their busy schedule.

BP27 (TS) had a 40-minute drive to and from the training facility while working full-time and was thus worried about her ability to attend all the sessions for the study, but wrote that the accountability of having scheduled sessions with the trainers helped keep her attendance high: "*My only apprehension was being able to stick to routine, but it definitely subsided by having accountability*."

Though DL34 (TS) struggled for years to be consistent with her workouts before the training study due to her busy schedule and feeling tired all the time, she had a revelation a mere 4 weeks into the intervention that exercising gave her energy rather than making her more fatigued: "*Apprehensions about whether or not I could be consistent has mostly subsided. Also, I have realized that though I claim to be 'always tired', exercising some days when I'm just moderately tired actually helps my energy level*." She further expressed that attending the sessions did not get in the way of her life as she'd worried and that her workout consistency boosted her motivation. "*I was apprehensive that I would actually make it through the study without any scheduling conflicts. [However,] I was able to make all my scheduled sessions without negatively impacting my career or home life…. Just knowing I can be consistent 3 times per week for 8 weeks has done wonders for my motivation and confidence*."

Theme 2: Body image struggles

All 14 participants mentioned struggling with their body image in some capacity prior to the intervention. They acknowledged that their negative self-talk was strong, yet they were working on improving upon it. By the end of the study, all of them experienced a noticeable improvement in their body image and particularly an appreciation for their body's functions as a result of resistance training and gaining strength but acknowledged that the body image struggles had not fully resolved.

"Sometimes I do not like my body." Every participant expressed conflicting feelings about their bodies. They commented that they appreciated their body's functions, yet still did not always like the way they looked. They fluctuated between gratitude for everything their body was able to do and sadness, shame, and anxiety over parts of their body that they felt were not good enough. This was captured in remarks such as, "*I am really proud of how strong my body is and am grateful for all it does for me. I still feel sad, ashamed, and uncomfortable at certain times (getting weighed, trying on old or new clothes, looking at old pictures) but am improving*" (AA01, HICT) and "*My body is beautiful. Sometimes I do not like my body :(Always battling body dysmorphia, but most days are better*." (CC38, TS)

"*Because I feel stronger, I'm not as worried about my body image."* By the end of the intervention, all 14 participants expressed that their body image had improved as a result of the training and the many ways this had positively impacted their lives. Several acknowledged the positive role that emphasizing performance over aesthetics played in their mental health with comments such as, "*Tracking progress that* *is not focused on body composition but rather focused on weights and repetitions deemphasizes the aesthetic side of exercise. Personally, for my own self-worth and mental health, I found this mindset to be beneficial and rewarding*" (RE30, HICT) and "*Because I feel stronger, I'm not as worried about my body image."* (BP27, TS)

Further, several participants expressed increased appreciation for their body independent of how they looked as a result of the training intervention.

"*I appreciate my body more which makes me feel more confident in how I look. This has improved my quality of life because I'm more comfortable and grateful for my body even though my body composition hasn't changed super drastically*." (AZ31, HICT)

Additionally, many experienced an increase in body functionality appreciation, which refers to appreciating everything your body is able to do. They acknowledged a sense of gratitude for their body's physical capabilities both inside and outside the gym.

*"I have mixed feelings [associated with my body]. Occasionally I struggle with thoughts like 'my legs are gross', which makes me feel sad and anxious. More often though, I feel grateful, to be able to move my body and lift heavy things. I feel strong and confident when I see my body do really amazing thing*s." (MS35, HICT)

The participants remarked that though their body image struggles had improved, they had not fully resolved, and they were still struggling with self-perception.

"*It's easy for me to pick my body apart in pictures, etc. but I'm also stronger than I was a month ago and I'm more physically capable than I was a month ago, so it's easier for me to stop the negative feelings from spiraling.*" (CM16, TS)

A few participants pointed out the role that society plays in women feeling this way about their bodies, thus recognizing that body image struggles were at least in part due to external pressures. For instance, CC38 (TS) commented, "*There are both subtle and in-your-face messages in the media and society that tell women to be small and lean. Resistance training can empower women to take back that strength that was already there!*" (CC38, TS) and similarly, JM43 (TS) pointed out, "*I have experienced most surface-level struggles such as body dysmorphia, anxiety, and burnout that have become more and more common in our society because of unrealistic expectations*."

Theme 3: Resistance training enjoyment

While all participants viewed their respective experiences in the study positively, 9 out of 14 participants specifically mentioned enjoying the workouts themselves. They noted experiencing an increase in overall motivation to exercise, feeling mentally and physically strong from pushing themselves during the sessions and lifting heavier than they would on their own, and feeling accomplished by the end of the workouts.

"I look forward to my strength training sessions." Several of the participants commented on an increase in motivation to exercise by the midpoint of the study.

"*I am more motivated to exercise and feel a lot of enjoyment from the training sessions themselves*." (AZ31, HICT)

Some specifically mentioned enjoying the style of training they had been randomly assigned to despite not practicing it regularly before.

"*I enjoyed circuit training so much that I plan to incorporate it into my training regimen. Normally I do traditional strength training, but circuit training is nice because it gets my heart rate up*." (JM44, HICT)

This general sentiment was shared between participants in both TS and HICT conditions.

"*I really enjoyed [the workouts] and enjoyed seeing the results and learning more about myself*." (SL36, TS)

"[I feel] spent! But strong." No participants mentioned disliking the workouts or the specific intervention they'd been assigned to; however, 6 of the 7 HICT participants voiced that they found the circuit sessions challenging and, in some cases, expressed a preference for TS. MD32 (HICT) wrote:
"*I've really enjoyed the experience of pushing hard, lifting heavier than I would on my own. It's hard when exercising, but I always feel good when I'm done*." Specifically, when asked about how she felt at the end of each workout, she responded, "*Spent! But strong. I feel mentally strong. It feels good to be doing something for myself*."

This experience was shared by other participants in the HICT condition.
"*I do get tired because I am in the circuit group, so it does get tiring having the short rest breaks, but once I take a few minutes, I feel good. I feel strong after the sessions, too, knowing I was able to lift as much as I did in the session*." (JG42, HICT)

MS35 admitted that CT was not her preferred style of resistance training and that she didn't always look forward to the workouts. "*I do dread it going in, but once I'm done, I do feel really good. Circuit training is tiring in the moment and the short rest periods are very difficult for me. This definitely makes circuit training less appealing to me and definitely makes lifting heavier much harder. I really enjoy lifting heavier, so that's the only downside of the circuit training*." Despite this, she expressed at the end of the intervention that she felt that HICT was a net positive. "*Circuit training isn't my favorite way to train, but every time I left the [training] lab, I felt like I was in a better mood, and it set the tone for the rest of the day*."

Amongst TS participants, only one specifically mentioned feeling tired during the sessions, but she enjoyed the way she felt by the end of each workout.

"*Exercising feels tiring during the sessions, but I still feel engaged and active…. I feel fatigued but not too tired. I also feel accomplished from completing the session*." (BP27)

Others shared that they felt the sessions were challenging but enjoyed pushing hard and felt better afterward, as captured by remarks such as "*Movements are challenging but not boring because I'm seeing my numbers or I'm learning better form, etc. Also, the movements are not so challenging that they feel impossible which is helpful as well*," (CM16) "*When I am exercising, I feel energized for the majority of the time… I feel great as I pushed through a hard session. I always usually feel high spirited after workouts*," (KG39) and "*I feel accomplished, proud of myself for pushing through a tough workout. I definitely feel the post-workout endorphin rush that leads to an increase in energy.*" (JM43)

"I felt a camaraderie with the other participants and the female trainers." Four of the 14 participants expressed that they enjoyed the camaraderie with others in the study. The social support they experienced seemed to have a positive impact on their enjoyment of the sessions.

"*I felt a camaraderie with the other participants and the female trainers that was empowering and encouraging*." (AZ31, HICT)

CM16 (TS), who completed her training sessions in the early evenings after a long day of work, noted, "*I'm excited to see progress and to see the team*." She was frequently observed engaging in animated discussion with others on various topics including Dungeons & Dragons and her favorite songs from the '90s during her rest periods between sets.

A few of the participants also pointed out the impact of the head trainer of the study on their overall training experience, as evidenced by comments such as "*I also feel like the support/feedback from the* *trainer has been ideal for me to keep coming back and able to lift more weight each time. I am so happy that I can lift heavy while being supervised for my form*" (CC38, TS) and "*The value of working with a trainer was above and beyond, and I'm grateful for the experience as it was so positive*." (AZ31, HICT)

"*Resistance training is empowering."* Several of the participants commented on how resistance training and the specific emphasis on getting stronger over time was empowering, allowing them to experience not only physical but also psychological benefits.

"It [resistance training] is a very empowering activity to do and affects not only physical appearance but also affects mental health in a positive way." (SL36, TS)

There was also mention of the role that resistance training played in managing societal expectations and pushing back against external pressures. This was captured in comments such as "*I think women resistance training is empowering! I love seeing women break the stigma and overcome the fear of becoming 'bulky'*" (MS35, HICT) and "*Resistance training can empower women to take back that strength that was already there!*" (CC38, TS)

Theme 4: Resistance training impact

All participants recognized the positive impacts resistance training had in their lives. Specifically, they observed an increase in confidence as a result of resistance training, performance improvements in the gym, better mood and overall psychological health, improved ADL, and better engagement in self-care activities such as proper diet and sleep management. The participants' experience in the study was so influential that all of them said they would recommend resistance training to other women.

"I gained confidence." Of the 14 participants, 13 mentioned experiencing an increase in confidence as a result of resistance training. Many expressed excitement over the personal records (PRs) they set throughout the study.

"*I gained a lot of confidence in myself! I would not have pushed myself as hard if I were on my own, so I am glad I was able to participate in this study. I did not think [when beginning the study] that I would be able to lift that much. Now, I know that I can do it and I am able to hit new PRs that I did not think I would have on my own*." (JG42, HICT)

Additionally, showing up consistently for the sessions was helpful, particularly for those who had previously expressed concern about their ability to attend all the workouts.

"[This experience] renewed confidence in my strength – something I haven't felt in years. Just knowing I can be consistent 3x per week for 8 weeks has done wonders for my motivation and confidence." (DL34, TS)

Further, KG39 (TS) recognized several wins when asked about her takeaways from the training intervention: "*I gained confidence, I gained inner strength, I saw an improvement in my overall mental health*."

"*I'm a happier person for my family."* Resistance training had a positive impact on the participants' mood even outside of the training sessions, both in terms of reducing negative mood states and increasing positive mood states. Some also mentioned an increase in productivity.

MD32 (HICT) wrote: "*I'm a happier person for my family*," while KG39 (TS) explained:

"*I feel I have been having less depressive moods, and I don't feel lazy or unproductive anymore. I have noticed a difference in my attitude and motivation to get things done. I feel generally more happy and feel that I can accomplish anything in my day*."

On a similar note, CM16 (TS) expressed, "*I have less anxiety/overwhelm overall*."

When asked about her psychological health at the end of the intervention, AA01 (HICT) wrote: "*Better. Than. Ever*."

"I was able to easily move heavy boxes of books." All 14 participants mentioned experiencing an increase in their quality of life and/or ADL. They found physical tasks even outside the gym easier to perform because of their increased strength. This was highlighted in several comments, including "*I was able to easily move heavy boxes of books that I would normally leave for my boyfriend to move. I am also having a much easier time at work [as a physical therapist], lifting patients, carrying my treatment table, etc*.," (AA01, HICT) "*I have improved overall quality of life (e.g. walking up the stairs without feeling too fatigued, improved aerobic abilities)*," (JM, HICT) and "*I have noticed that certain things that I was able to do before that were challenging are a lot less challenging (e.g. bringing in groceries from Costco feels a lot less heavy than it did previously). My mobility is up as well – I'm able to move in ways that I did not feel as confident with before*." (CM16, TS)

"My diet has improved drastically." By the mid-point of the intervention, 8 participants noted that they were more cognizant of their diet, sleep, and stress to properly fuel performance during training sessions. They reported their motivations for taking care of themselves outside the gym increased.
"*With less anxiety [due to resistance training], I'm sleeping better, have had less stress overall, and have been eating healthier.*" (CM16, TS)

Some participants also observed that they were better at engaging in self-care activities, such as sleep, skincare, and proper diet.
"*Weight lifting motivated me to shower more consistently at night, which then led me to be more consistent with my skincare! I also found my eating habits to be more consistent, and I chose healthier*

foods during the study. It made more sense to adopt a diet that was higher in protein and more fruits and vegetables so that I didn't feel fatigued during the workouts." (CC38, TS)

SL36 (TS), a self-professed under-eater who often forgets to eat and loses her appetite, particularly when struggling with her mental health, observed that she was much better about eating enough food 4 weeks into the intervention:

"*My diet has improved drastically this past month. I'm eating three meals a day, but also eating snacks in between and even starting to get my cravings back. This experience helped me understand my body more in terms of what I need and how many hours of sleep I needed or how much water I should be drinking*."

Participants started caring about their sleep quantity and quality more to ensure that they could continue to have good workouts: "*I learned to re-arrange my schedule to prioritize both working out and getting enough sleep to not be too drained to work out*, " (AA01, HICT) while others mentioned that the training sessions helped improve their sleep overall: "*With less anxiety [due to lifting], I'm sleeping better, have had less stress overall, and have been eating healthier*." (CM16, TS)

Additionally, having a qualified trainer in charge of the workouts reduced the mental load for some of the participants, thereby providing some stress relief.

"*I noticed stress was a lot lower because I didn't have to think too much about what I was doing in the gym, and having the guidance of a trainer/instructor was somewhat of a relief mentally*." (MS35, HICT)

"Every woman should be resistance training." When asked whether the study met their expectations, 7 responded yes, while the other 7 stated that their expectations were exceeded. Participants expressed relief due to not incurring injury, pride for attending sessions, and surprise at how much progress they had made in an 8-week timespan.

All 14 participants said they would recommend other women resistance train due to its physical and mental health benefits.

"*It [lifting] would be tremendously positive [for women]. Psychologically, [it] would be great for confidence, improvement in body image, and overall quality of life. Physically, you would be functionally stronger (groceries etc.) and also reap a myriad of health benefits, both short and long term. Every woman should be resistance training*." (AA01, HICT)

Some were inspired by their experience in the training study to encourage others to resistance train as well.

"*I have found so much peace doing this [study] and felt so confident and motivated to continue now that I am done with the intervention that I am inspired to help others and continue in my goals*." (CC16, TS)

Section 4: Discussion

Our study found that HICT and TS were both acceptable forms of resistance training, with some women finding HICT more challenging but ultimately rewarding, even if it wasn't something they would normally do. A common theme was that the supervised group nature of the training provided a host of benefits, including accountability, a reduction in the risk of injury (perceived or actual), encouragement to push themselves hard, and camaraderie and support from other women. Participants reported feeling much stronger and more capable in their daily lives after undertaking the program. Additionally, all participants reported improvement in their well-being, general strength, and ADL.

The participants' continual mention of increased confidence as well as the simultaneous increase in enthusiasm for resistance training lends support to the idea that self-efficacy is a key factor in predicting exercise behavior [48, 49]. Self-efficacy refers to an individual's belief in their own capacity to perform specific tasks to achieve a goal and is considered one of the primary factors of health-promoting behavior [221, 222]. In addition to a higher likelihood of beginning and adhering to an exercise program, those with higher self-efficacy are also more likely to recognize the benefits of their exercise behavior [184]. This is important as not believing in a behavior's benefits makes it unlikely that adherence to said behavior will continue over the long term, even if self-efficacy is high.

As self-efficacy is a reliable predictor of long-term exercise behavior [47, 48, 223, 224], the participants' responses suggest a higher likelihood of continuing to resistance train over the long-term despite the training intervention being only 8 weeks in duration. Further, higher self-efficacy means that an individual is likely to persist with a behavior despite obstacles and impediments [225] such as a busy schedule and feeling tired, as often is the case with everyday life. Self-efficacy is desirable as it means individuals who engage in long-term resistance training will continue to reap the many physical and mental health benefits of the behavior year after year, which in turn will also help prevent many age-related declines in health such as sarcopenia, bone loss, metabolic decline, and more.

The observation that participants experienced improvements in areas of their lives outside the gym as a result of the training intervention supports Bandura's idea of generality of perceived self-efficacy [226]. Bandura stated that enhanced self-efficacy tends to generalize to other situations, particularly in activities most similar to the ones in which self-efficacy has increased. Specifically, in the resistance training impact theme, participants perceived that they were able to perform daily activities more independently and with more ease than before, such as when moving heavy boxes. Further, participants improved their self-care activities as a byproduct of resistance training consistently. These activities included keeping up with their skincare routine and managing their sleep.

Social interaction can also be an important element of exercise adherence as it can provide individuals with enjoyment, verbal encouragement, vicarious experiences, and informational and emotional support [61]. Social support and self-efficacy are two facilitators of long-term exercise behavior [38, 39]. Social support includes not only fellow exercisers who can help generate a positive, uplifting environment, but also a supportive instructor/trainer who can provide valuable instruction, boost confidence, and help individuals feel noticed and more secure about themselves [38]. Indeed, there is some evidence that interventions conducted in group settings with a common goal (as was the case for our study) provide an increased sense of social connectedness, which may be a crucial component of regular exercise adherence [224].

The participants noted at both the mid-point and at the end of the training intervention that resistance training enhanced their quality of life, hinting at increased intrinsic motivation, which refers to participating in a behavior for the inherent enjoyment and satisfaction of the behavior itself [227]. This positive reinforcement likely created a cycle, in which the regular resistance training made them feel good about their health and well-being, which then made them feel good about themselves, and in turn further motivated them to continue resistance training [38]. Their experiences are in line with self-determination theory, which posits that motivations for exercise evolve over time from extrinsic to intrinsic [227]. Importantly, regular exercisers are more intrinsically motivated to improve their quality of life, and intrinsic motives are related to enhanced psychological well-being [228].

A recurring theme throughout the study for all participants was body image struggles. These struggles stem in large part from sociocultural pressures to conform to a body ideal; for women, the "thin ideal" especially is espoused as the pinnacle of feminine beauty in Western cultures [229]. The prevalence of body image dissatisfaction amongst women in the United States has been reported to be anywhere from 11-72% [230], which is a concern as negative body image is linked to emotional distress [231], social anxiety [232], depression [233], eating disorders [234], and other psychological challenges.

Compared to a non-exercising control group, exercise improves body image [235]. Resistance training in particular fosters positive body image and self-efficacy [151]. Cash's cognitive-behavioral model of body image cites physical characteristics, cultural socialization, interpersonal experiences, and personality variables as the four developmental influences of body image [236], each of which the participants in our study alluded to in their experiences. Additionally, emphasizing the non-weight loss benefits of exercise may help improve body image and in turn, improve exercise adherence [39]. Notably, while the participants experienced improved body image, their struggles did not fully resolve. The question remains as to whether the participants' experiences related to their body image would continue to improve beyond the 8-week intervention, plateau, or fluctuate over time.

Many of the participants focused more on body functionality than body aesthetics throughout the intervention. Body functionality refers to everything the body is able to do across multiple domains and includes not only physical capabilities (e.g. lifting weights, carrying boxes) but also internal processes (e.g. digesting food), creative endeavors (e.g. writing a poem), communication with others (e.g. via body language), and self-care (e.g. sleeping) [237]. While body functionality alone is not considered a component of body image, body functionality appreciation represents the juncture between body functionality and body image and places emphasis on appreciating what the body can do [238]. Increasing body functionality appreciation can significantly improve body image [237] , and despite not explicitly undergoing a body functionality intervention, the participants experiences reflected body functionality appreciation which may have led, as a byproduct, to the reported improvements in body image.

Finally, this qualitative study builds on previous research on the impacts of resistance training on quality of life. A 12-week resistance training in previously inactive overweight women led to an increase in exercise motivation and self-perceived health [239]. Meanwhile, a meta-analysis found that general exercise training induced positive changes in vitality, mental health, and quality of life [240], and another meta-analysis found that resistance training specifically induced improvements in health-related quality of life in older adults [15]. While prior research on the impact of resistance training on quality of life shows consistently positive outcomes [241], there are no data on middle-aged and younger women. However, our findings support the hypothesis that future quantitative work would uncover similarly positively outcomes for women engaged in resistance training.

In agreement with the results of the current study, previous research suggests that resistance training can improve self-efficacy [49], body image [151, 235], and quality of life [15, 240]. However, given the various forms of resistance training to choose from, qualitative investigations such as the present analysis provide a better understanding of their unique impacts on different individuals. This can aid practitioners in exercise prescription and variation to enhance long-term adherence.

There are several strengths to this study. This is the first study that the authors are aware of that explored the qualitative impacts of HICT vs. TS in trained women, thus it spotlights an underrepresented cohort in resistance training research. Additionally, the use of QD allows researchers to remain close to the data, relying heavily on the participants' own words to generate themes. Further, the use of open-ended questions allowed the researchers to capture insights that may not have otherwise been obtained through quantitative questionnaires.

There are some limitations to this study. While QD stays close to the data, this can also make the analytical process subjective as descriptions rely on the researcher's interpretations, inclinations, and sensitivities. It is therefore crucial to approach QD with as much integrity and neutrality as possible, reflecting on potential researcher bias and involving peer review / researcher triangulation [220, 242]. Additionally, the flexibility and variability in QD methods may lead to confusion for readers and fellow researchers, and those unfamiliar with qualitative studies may struggle to differentiate QD with hints of other qualitative approaches from "grounded theory, phenomenological, and ethnographical research" [219]. Additionally, the data might not be representative of the target population at large as many participants were recruited through social media and were local to the training facility. Future research should include the experiences of more women to encourage more diverse insights into their resistance training experiences.

Section 5: Practical applications

Given women's low participation rates in resistance training, better understanding the experiences of those who regularly resistance train is invaluable. These findings demonstrate participants in HICT and TS enjoyed their resistance training interventions, with both groups reporting perceived health benefits, both physically and mentally.

The participants' responses indicate the importance of a strong social environment with a supportive instructor on an individual's adherence and enjoyment. Therefore, gyms and practitioners may see improved uptake and consistency by making a concerted effort to foster a welcoming, encouraging environment for women in the weight room, perhaps by offering group training sessions specifically to those who prefer training with other women.

Given the initial hesitance due to injury risk and technical execution, the presence of a trainer to provide demonstration and guidance on form and exercise execution may make it more likely that women will attend training sessions. Further, emphasizing performance accomplishments, such as improving technique or increasing total load and/or number of repetitions performed, rather than focusing on weight loss or other aesthetic changes, may play a role in improving women's body image and self-efficacy. Therefore, knowledgeable, welcoming trainers should be involved in training or providing support for women in the weight room. Ideally, these trainers should provide messages that de-emphasize changes in body weight or composition, focusing instead on body functionality appreciation. Ensuring a positive and safe training atmosphere may serve to maintain women's interest in resistance training.

As some participants expressed a potential preference for one modality over another, personal preference should be taken into consideration when determining whether an individual should participate in HICT, TS, or another form of resistance training. Time availability is another factor to consider, as more time-efficient training strategies such as HICT can allow for similar exercise volume to be performed in less time. Additionally, as HICT involves taking up multiple pieces of equipment at once, equipment availability and the general gym setting should be assessed to determine whether HICT is a viable option for an individual and if so, what exercise selection would work best. Some practical solutions, such as bringing a pair of DBs over to a machine to use in tandem, may be more feasible than occupying two machines simultaneously, especially during peak times at commercial gyms.

Ultimately, providing opportunities and continued encouragement for more women to consistently engage in resistance training is an ongoing challenge. Implementing the methods recommended above will help to address this problem and ensure that more women benefit from resistance training.

Chapter 7 General discussion

Section 1: Discussion

The overall purpose of this thesis was to determine the effects of HICT and TS on physiological and psychological responses in trained women. The review of literature (Chapter 2) revealed that resistance training adherence rates are lower in women compared to men due to numerous barriers including social, psychological, and time-effort. In addition, while there exists some research on the impacts of TS on women, the research on the impact of HICT on women is scant, and there are zero studies to date that directly compare HICT versus TS amongst trained women. Therefore, several investigations were conducted to systematically address these gaps in the literature.

The first investigation established the practices, preferences, and perceived benefits and barriers to resistance training amongst women (Chapter 3). Of the participants surveyed, 71.95% met the threshold of resistance training a minimum of twice a week as set by the NSCA, 12.77% reported resistance training but did not meet the threshold, and 15.29% reported not resistance training at all (Chapter 3). Those who did resistance train regularly scored significantly higher than recreationally trained lifters on preference for presence of instructions/planning, ability to perform resistance training exercises, and routine, and also on agreement with the statement “I like to resistance train” (Chapter 3). Further, regular resistance trainers perceived greater benefits and fewer barriers compared to recreationally trained lifters and non-lifters. The findings suggested making effort to reduce the perceived time-effort, physical, social, and specific barriers to improve overall resistance training adherence rates for women.

Previous research identified numerous benefits of two popular styles of resistance training, TS and HICT. However, a direct comparison of the physiological and psychological impacts of HICT versus TS in trained women had not been conducted. Chapters 4, 5, and 6 were therefore designed to answer this question. Consistent with existing research on the acute impacts of HICT versus TS in trained men [98], an acute HICT session elicited greater physiological (BLA, HR) and psychological (sRPE, state anxiety) compared to an acute TS session in trained women (Chapter 4). Meanwhile, self-efficacy scores similarly increased following both HICT and TS (Chapter 4). Additionally, HICT was completed in less time compared to TS, thus HICT could be recommended as a favorable training modality for women looking for physiologically effective, time-efficient workouts, provided they are adequately motivated and prepared for higher sRPE (Chapter 4).

Next, a longitudinal randomized parallel group trial was conducted to compare the effects of HICT versus TS on strength, muscle girth, and body composition in trained women (Chapter 5). After 8 weeks of training, HICT and TS yielded similar increases in strength and LBM and a decrease in body fat percentage (Chapter 5). Further, there was no statistically significant change in muscle girth, skinfold thickness, body mass, or FM in both groups (Chapter 5). This study demonstrated that even with shorter rest periods and overall shorter training sessions, similar strength and LBM gains can be achieved provided working sets are terminated close to muscular failure (Chapter 5).

Finally, Chapter 6 explored the impact of HICT and TS on psychological measures in trained women. A common theme was that the supervised nature of the training study provided multiple benefits such as accountability, a reduction in the perceived or actual risk of injury, increased encouragement for participants to push themselves during the workouts, and support from others. A repeated observation made was increased confidence and increased enthusiasm for resistance training throughout the intervention. The participants noticed an improvement in their well-being, body image, strength, and ADL, with some women finding HICT more challenging but still rewarding to perform.

With all this being said, how do HICT and TS impact physiological and psychological responses in trained women? When sets are terminated close to muscular failure, it appears that the physiological and psychological benefits of HICT and TS are similar. Both training styles similarly increase strength and LBM while decreasing body fat percentage with non-significantly different volume loads, while HICT sessions were completed in less time compared to TS. On an acute level, HICT had greater physiological (BLA, HR) and psychological (sRPE, state anxiety) stress compared to TS, while self-efficacy similarly increased in both groups. Additionally, both training styles increase confidence, enjoyment of resistance training, ADL, and overall quality of life in the context of a strong social environment while also improving body image by emphasizing the body’s capabilities over aesthetics.

Section 2: Limitations

There are several limitations to the research contained in this thesis. First, while the sample size of the survey in Chapter 3 was large, the participants were not representative of the broader population of women as they were recruited from SLC and ERH’s social media platforms which focus on health and fitness education. The primary limitation of Chapters 4, 5, and 6 was small sample size. In Chapter 5, body composition testing conditions were not fully standardized across all participants, as some did not remain fasted in the hours leading up to their DXA scans as requested, and the timing of their assessments were not always consistent from pre- to post-intervention. Diet was also not controlled for in Chapters 5 and 6, thus while participants were asked not to change their diet throughout the duration of the study, it is possible that they may have subconsciously altered their calorie intake and/or food choices. Finally, given the participant, the findings of the studies in Chapters 3, 4, 5, and 6 unfortunately cannot necessarily be extrapolated to different populations and training programs utilizing different exercises.

Section 3: Practical applications

Based on the findings of this thesis, the practical recommendations are as follows:

- HICT is recommended for women who want a higher cardiovascular stress response during training with reduced session length provided they have the desire and capacity to train with higher perceived exertion.
- For increasing strength and LBM and decreasing body fat percentage, HICT and TS are similarly effective. Factors such as personal preference, time constraints, gym setup, and ability to sustain a higher work:rest ratio should be taken into consideration to determine the best training style for the individual.
- Gyms and practitioners should take a multi-pronged approach to reduce the perceived time-effort, physical, social, and specific barriers to resistance training against women. This can include promoting programs shorter in duration utilizing limited equipment that can be completed in their own homes, time-saving strategies such as CT, supersets, and dropsets, providing more beginner-level workouts and tutorials, and connecting women with mutual interest in resistance training, both in-person and virtually. Additionally, no-tolerance policies against harassment, bullying, or intentional intimidation can be implemented in gyms, and more female trainers can be hired to make women feel more welcome in the weights section of gyms.

- As a strong social environment can positively impact resistance training adherence and enjoyment, gyms and practitioners may see increased participation rates amongst women by fostering a welcoming, encouraging environment for women in the gym and organizing group training sessions for those who prefer training with other women.
- The presence of a qualified trainer to provide demonstration and guidance on form and execution can also help increase adherence rates.
- Trainers should de-emphasize changes in body weight or body composition and instead foster body functionality appreciation during training sessions to improve women's body image.

Section 4: Recommendations for future research

- Chapter 2 established that resistance training adherence rates are lower amongst women compared to men due to multiple factors including social, psychological, time-effort, and more. Future research is needed to systematically assess the impact of addressing these specific perceived behaviors. For example, how effectively would providing better instruction and support for women in the gym increasing adherence rates? What about providing minimal equipment, time-efficient workouts women could do from the privacy and comfort of their own homes?
- Chapter 3, which aimed to understand resistance training preferences, practices, and perceived benefits and barriers amongst women, surveyed participants pooled from social media with an interest in health and fitness information. Future research should utilize a more diverse sample, particularly recruiting more participants who are not currently resistance training to better understand their perceived barriers. Additional research can also be conducted to better elucidate the differences in perceived benefits and barriers to resistance training in men versus women to help understand the discrepancy in participation rates.
- Chapter 4 established that on an acute level, HICT had greater physiological and psychological stress compared to TS. However, the outcome variables were limited to BLA, HR, sPRE, state anxiety, and self-efficacy. Future research can include additional measures such as VO_2, affect,

and perceived behavioral control to further understand differences in physiological and psychological responses between the two training modalities.

- Chapter 5 confirmed that HICT and TS yielded comparable increases in strength and LBM and a decreased in body fat percentage in women. However, as diet was not controlled for, future research is needed with diet standardized between training conditions. Additionally, future research with larger sample sizes is needed to confirm our findings.
- Chapter 6 revealed that HICT and TS both provided a plethora of physical and mental health benefits. However, as the participants were all between the ages of 18 and 40, future qualitative research is needed to better understand how resistance training impacts quality of life on middle-aged and younger women. Further, more women of various backgrounds in general need to be included in studies to gain insight into their resistance training experiences.

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Appendices

Appendix A AUT Ethics approval (Chapter 3)

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
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3 November 2021

Eric Helms
Faculty of Health and Environmental Sciences

Dear Eric

Re: Ethics Application: **21/291 Resistance training preferences, current practices, perceived benefits, and barriers in women**

Thank you for your responses to the conditions for the amendment to your ethics application.

The amendment to the recruitment protocol and minor changes to the survey has been approved.

Standard Conditions of Approval.

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted. When the research is undertaken outside New Zealand, you need to meet all ethical, legal, and locality obligations or requirements for those jurisdictions.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Appendix B AUT Ethics approval (Chapters 4, 5, and 6)

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
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T: +64 9 921 9999 ext. 8316
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22 March 2022

Eric Helms
Faculty of Health and Environmental Sciences

Dear Eric

Re Ethics Application: **22/16 The acute effects of circuit versus traditional strength training on psychological and physiological outcomes in trained women**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 22 March 2025.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: sohee.lee25@gmail.com

Appendix C IRB approval (Chapter 4)

California State University SAN MARCOS

Institutional Review Board for the Protection of Human Subjects (IRB)

California State University San Marcos San Marcos, CA 92096-0001

Tel: 760.750.4029. **Fax:** 760.750.3150 irb@csusm.edu www.csusm.edu/irb

DATE:	September 21, 2022
TO:	Matt Schubert, Ph.D.
FROM:	California State University, San Marcos Institutional Review Board
PROJECT TITLE:	[1925057-2] The acute effects of circuit versus traditional strength training on psychological and physiological outcomes in trained women
REFERENCE #:	
SUBMISSION TYPE:	Amendment/Modification
ACTION:	APPROVED
APPROVAL DATE:	September 21, 2022
EXPIRATION DATE:	N/A
REVIEW TYPE:	Expedited Review

This letter certifies that the above referenced project was reviewed and APPROVED by the CSUSM Institutional Review Board (IRB) in accordance with the requirements of the Code of Federal Regulations on Protection of Human Subjects (45 CFR 46), including its relevant subparts. Please note that all research records must be retained for a minimum of three years after the completion of the project.

If applicable, all approved forms and materials (consent forms, information forms, flyers etc.) have been uploaded to IRBNet under "Board" documents. Only approved consent forms may be used to obtain participant consent.

Modifications to Research Protocol
Changes to this protocol (procedures, populations, locations, personnel, etc.) must be submitted and approved by the IRB prior to implementation using the "Minor Modification" application form available on IRBNet.

Unanticipated Outcomes/Events
All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this committee. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this committee.

Continuing Review
Continuing reviews for limited/expedited protocols are no longer required as part of the IRB process, per the partial early implementation of the federal Common Rule policy retroactive from July 19th, 2018. Should any changes to your study occur, please submit a minor modification using the application form available on IRBNet. If this is a full review, please submit a continuing review at least 30 days before the annual expiration date.

If you have any questions, please contact the IRB office at CSUSM by calling (760) 750-4029 or by email to irb@csusm.edu. Please include your project title and reference number in all correspondence with this committee.

Wishing you well with your research,

CSUSM IRB

Appendix D IRB approval (Chapters 5 and 6)

California State University
SAN MARCOS

Institutional Review Board for the Protection of Human Subjects (IRB)
California State University San Marcos   San Marcos, CA 92096-0001
Tel: 760.750.4029.   **Fax:** 760.750.3150   irb@csusm.edu   www.csusm.edu/irb

DATE:	June 22, 2022
TO:	Matt Schubert, Ph.D.
FROM:	California State University, San Marcos Institutional Review Board
PROJECT TITLE:	[1925058-1] The chronic effects of circuit versus traditional strength training on psychological and physiological outcomes in trained women
REFERENCE #:	
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	June 22, 2022
EXPIRATION DATE:	N/A
REVIEW TYPE:	Expedited Review

This letter certifies that the above referenced project was reviewed and APPROVED by the CSUSM Institutional Review Board (IRB) in accordance with the requirements of the Code of Federal Regulations on Protection of Human Subjects (45 CFR 46), including its relevant subparts. Please note that all research records must be retained for a minimum of three years after the completion of the project.

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If you have any questions, please contact the IRB office at CSUSM by calling (760) 750-4029 or by email to irb@csusm.edu. Please include your project title and reference number in all correspondence with this committee.

Wishing you well with your research,

CSUSM IRB

Appendix E Survey questions from Chapter 3

This is a URL to access the survey questions that were used for Chapter 3

https://aut.au1.qualtrics.com/jfe/form/SV_b4rLQK3D6hlJ7ts