EFFECTS OF INDIVIDUALIZED EXERCISE PRESCRIPTION VS. GENERAL GUIDELINES ON CARDIORESPIRATORY FITNESS, EXERCISE PERFORMANCE, AND ANTHROPOMETRY IN OVERWEIGHT AND OBESE SUBJECTS

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ABSTRACT

Parviainen, A. 2022. Effects of individualized exercise prescription vs. general guidelines on cardiorespiratory fitness, exercise performance, and anthropometry in overweight and obese subjects. University of Jyväskylä, master's thesis, 52 pages.

Background and objective. Individualized exercise approaches are required as physical inactivity has remained a health problem that has not been affected by information in different medias and general exercise guidelines given by authorities. The aim of this study was to analyze if individually tailored multidisciplinary interventions determine improvements in anthropometry, cardiorespiratory fitness (CRF) and exercise performance in between 18 to 40 years old sedentary individuals with obesity.

Methods. Totally 145 persons were contacted, and the initial sample consists of 89 subjects, who were randomized into three groups. 56 of the participants took part to measurements after 3 months. Group 1 (n=14) represents current general exercise and nutrition guidelines, while Group 2 (n=22) personalized intervention approach and Group 3 (n=20) highly personalized intervention approach. Before and after 12 weeks of training, oxygen consumption (VO_2), exercise performance (W) and heart rate (HR) at ventilatory threshold1(VT1), ventilatory treshold2(VT2) and at peak level were assessed during a step-incremental cycle-ergometer exercise test. Also, anthropometrical values of weight (kg), Body Mass Index (BMI), Body Fat percent (BF%) and Fat Free Mass (FFM) were assessed. At group 2 and 3 mobile and cloud technologies were used to fine tune the intervention based on subjective feedback and emotions, exercise and recovery data, and nutrition data accumulating during the intervention period.

Results. Group 3 had a statistically significant decrease in mean weight 1.8 ±1.6% ($p<0.01$), BMI 1.8 ±0 % ($p< 0.05$) and bodyfat 3.7 ±4.3% ($p<0.05$) after 12 weeks of training intervention, but no change in FFM. Group 3 had statistically significant increase in VO_{2peak} values: l/min 6.8 ±9.3% ($p<0.01$), ml/kg/min 8.9 ±23.3% ($p<0.01$), ml/ffm/min 6.4 ±31.8% ($p<0.05$), at VT1 13.1 ±9.4% ($p<0.01$), 15.5 ±28.6% ($p<0.01$), 6.4 ±17.6% ($p<0.01$) and VT2 13.1±4.1% ($p<0.01$), 15.5 ±18.4% ($p<0.01$), 6.4 ±4.7% ($p<0.05$). Group 1 and 2 had no statistically significant changes i any anthropometrical or VO_2 variable. All the groups had statistically significant increases in power output at peak level (on average12, 12 and 16W, respectively). Group 2 and 3 also had significant increase at VT1 10 and 14W and VT2 10 and 15W, respectively. Changes in cardiorespiratory fitness were mostly independent from changes in anthropometry. All participants had significant drop in HR (3%, $p<0,05$) and diastolic blood pressure (5%, $p<0,01$), but not in systolic blood pressure or rate of perceived exertion (RPE) at moderate exercise intensity (60W female/ 80W male).

Conclusions. This study suggests that highly personalized training interventions are more effective in producing positive changes in cardiorespiratory fitness, exercise performance, and anthropometry than those following general guidelines. Improving and measuring cardiorespiratory fitness is more important than to follow anthropometrical values to get initiation and progress of an effective lifestyle intervention. Technology alone is not the answer to get people motivated to increase their physical activity. Improvement reached in exercise performance helps participants to survive at their daily physical activities and continue physical training.

Key words: randomized trial, obesity, exercise interventions, physical activity, maximal oxygen uptake, power output, anthropometry, ventilatory thresholds

ABSTRAKTI

Parviainen, A. 2022. Yksilöllisen liikuntaintervention vaikutukset vs. yleiset ohjeet kardiorespiratoriseen kuntoon, suorituskykyyn ja antropometriaan ylipainoisilla ja lihavilla henkilöillä. Jyväskylän yliopisto, pro gradu -tutkielma, 52 sivua.

Tausta ja tavoite. Yksilöllisiä liikuntainterventioita tarvitaan, koska fyysinen passiivisuus on pysynyt kansanterveydellisenä ongelmana, johon eri medioissa olevat tiedot ja viranomaisten antamat yleiset liikuntaohjeet eivät ole juurikaan vaikuttaneet. Tämän tutkimuksen tavoitteena oli analysoida, vaikuttavatko yksilöllisesti räätälöidyt monitieteiset interventiot antropometrian, kardiorespiratorisen kunnon (CRF) ja liikunnan suorituskyvyn paranemiseen 18–40-vuotiailla liikunnallisesti passiivisilla henkilöillä, joilla on liikalihavuutta.

Menetelmät. Yhteensä 145 henkilöön otettiin yhteyttä, joista asetettujen kriteereiden mukaisesti valikoitui 89 koehenkilöä, jotka satunnaistettiin kolmeen ryhmään. Osallistujista 56 osallistui loppumittauksiin 3 kuukauden kuluttua. Ryhmä 1 ($n =14$) edustaa nykyisiä yleisiä liikunta- ja ravitsemusohjeita, kun taas ryhmä 2 ($n = 22$) henkilökohtaista interventiota ja ryhmä 3 ($n = 20$) erittäin yksilöllistä interventiota. Ennen ja jälkeen 12 viikon harjoittelun, hapenkulutusta (VO_2), suorituskykyä (W) ja sykettä (HR) mitattiin ventilaatiokynnyksillä (VT1 ja VT2) sekä maksimitasolla asteittain nousevalla polkupyöräergometritestillä. Myös painon (kg), painoindeksin (BMI), kehon rasvaprosentin (BF%) ja rasvattoman massan (FFM) arvot mitattiin. Ryhmän 2 ja 3 osalta mobiili- ja pilviteknologioita käytettiin hienosäätämään interventiota subjektiivisen palautteen ja tunteiden, liikunta- ja palautumistietojen sekä interventiojakson aikana kertyvien ravitsemustietojen perusteella.

Tulokset. Ryhmän 3 keskipaino laski tilastollisesti merkitsevästi 1,8 ±1,6 % ($p<0,01$), BMI 1,8 ±0 % ($p< 0,05$) ja kehon rasvaprosentti 3,7 ±4,3 % ($p<0,05$) 12 viikon harjoittelujakson jälkeen, mutta FFM:ssä ei tapahtunut muutosta. Ryhmän 3 VO_{2peak}-arvot kasvoivat tilastollisesti merkitsevästi: l/min 6,8 ±9,3 % ($p<0,01$), ml/kg/min 8,9 ±23,3 % ($p<0,01$), ml/ffm/min 6,4 ±31,8 % ($p<0,05$), VT1 13,1 ±9,4 % ($p<0,01$), 13,1 ±9,4 % ($p<0,01$), 13,1 ±9,4 % ($p<0,01$), 13,1 ±9,4 % ($p<0,01$), 115,5 ±28,6 % ($p<0,01$), 6,4 ±17,6 % ($p<0,01$) ja VT2 13,1±4,1 % ($p<0,01$), 15,5 ±18,4 % ($p<0,01$), 6,4 ±4,7 % ($s<0,05$). Ryhmillä 1 ja 2 ei ollut tilastollisesti merkitseviä muutoksia missään antropometrisissä tai VO_2-muuttujissa. Kaikilla ryhmillä tehontuotanto kasvoi tilastollisesti merkitsevästi huipputasolla (keskimäärin 12, 12 ja 16 W). Ryhmien 2 ja 3 osalta tehontuotanto kasvoi merkitsevästi VT1 (10W ja 14W) ja VT2 tasoilla (10W ja 15W). Kardiorespiratorisen kunnon muutokset olivat enimmäkseen riippumattomia antropometrian muutoksista. Kaikilla osallistujilla oli merkittävä lasku sykkeessä (3 %, $p<0,05$) ja diastolisessa verenpaineessa (5 %, $p<0,01$), mutta ei systolisessa verenpaineessa tai koetun rasituksen osalta (RPE) kohtalaisella harjoitusintensiteetillä (60W nainen / 80W mies).

Johtopäätökset. Tämä tutkimus osoittaa, että erittäin henkilökohtaiset harjoitusinterventiot tuottavat tehokkaammin positiivisia muutoksia kardiorespiratorisessa kunnossa, suorituskyvyssä ja antropometriassa kuin ne, jotka noudattavat yleisiä ohjeita. Yksilön kardiorespiratorisen kunnon parantaminen ja mittaaminen on tärkeämpää kuin seurata antropometrisiä arvoja tehokkaan elämäntapaintervention aloittamiseksi ja edistämiseksi. Teknologia yksin ei ole vastaus siihen, että ihmiset motivoituvat lisäämään fyysistä aktiivisuuttaan. Suorituskyvyssä saavutettu parannus auttaa osallistujia selviytymään päivittäisissä fyysisissä aktiviteeteissaan ja jatkamaan fyysistä harjoittelua.

Avainsanat: satunnaistettu tutkimus, liikalihavuus, liikuntainterventiot, fyysinen aktiivisuus, maksimaalinen hapenottokyky, tehontuotto, antropometria, ventilaatiokynnykset

ABSTRACT

ABSTRAKTI

ABBREVIATIONS

ACSM	American College of Sport Medicine
BMI	Body Mass Index
BFP	Body fat percent
CHD	Coronary heart disease
CI	Confidence interval
CO	Cardiac output
CPET	Cardiopulmonary exercise test
CRF	Cardiorespiratory fitness
CVD	Cardiovascular disease
ET	Exercise training
FM	Fat mass
FFM	Fat free mass
FITT	Frequency, Intensity, Time (duration of exercise), and Type (mode of exercise)
HF	Heart failure
HR	Heart rate
LM	Lean mass
LPA	Light physical activity
MET	Metabolic Equivalent of Task
MHO	Metabolically healthy obese
MoMaMo!	Motivation Makes the Move
MONW	Metabolically obese – normal weight
MPA	Moderate physical activity
PA	Physical activity
PF	Physical fitness
PAG	Physical Activity Guidelines
PCOS	Polycystic ovary syndrome
RPE	Rate of perceived exertion

SMM	Skeletal muscle mass
V_E	Ventilatory expired
VPA	Vigorous physical activity
VO_{2max}	Maximal oxygen uptake
VO_{2peak}	Peak oxygen uptake
VO_{2VT1}	Oxygen uptake at ventilatory threshold 1
VO_{2VT2}	Oxygen uptake at ventilatory threshold 2
VT1	Ventilatory threshold 1
VT2	Ventilatory threshold 2
WHO	World Health Organization

1. INTRODUCTION

Due to the epidemic overweight/obesity and physical inactivity, the societies in general and the healthcare systems are facing new challenges and increased budgetary pressure. In most countries, health care currently lacks knowledge and tools in promoting physical activity in patients with or at risk for chronic diseases and complications such as an increased risk of obesity, metabolic syndrome, diabetes, cardiovascular disease, mental, cognitive, and musculoskeletal disturbances, as well as cardiovascular and all-cause mortality. “Exercise more and eat healthier” sounds easy advice but is difficult for many to follow in their daily life. Despite awareness of unhealthy lifestyle and perceived susceptibility of disease, overweight individuals are more likely to drop out of the course and little is known about how best to change sedentary behaviour in adults. Targeted, individualized approaches are needed because, despite major efforts, physical inactivity has remained a health problem that has not been affected by mass communications.

There is a need for developing individually tailored interventions for at-risk individuals. These interventions and models should highlight the need to identify strategies and techniques to enhance adherence and completion of programs.

The overarching goal in Motivation Makes the Move (MoMaMo!) project has been to develop truly individually tailored multidisciplinary interventions for at-risk individuals. And to develop an operational model to guide initiation and progress of an effective lifestyle intervention focusing on promoting citizen engagement in health and wellbeing by prevention and treatment of overweight/obesity and diseases that mainly are due to inactive, sedentary lifestyle.

Motivation Makes the Move! (MoMaMo!) aims to:

1) Decrease sedentary lifestyle, obesity, and their consequences.

To develop and validate lasting and individualized IT-assisted behavior change methodologies and best practices for citizen engagement in health, wellbeing, and prevention of diseases.

2) Enhance business opportunities in health care, wellness industry and consumer market.

Based on strengthened holistic evidence and improved knowledge about individuals’ behavior related to wellbeing, disease prevention and management. Due to the epidemic overweight/obesity and physical inactivity, the societies in general and the healthcare systems are facing new challenges and increased budgetary pressure. In most countries, health care currently lacks knowledge and tools in promoting physical activity in patients with or at risk for abovementioned chronic diseases and complications. Despite awareness of unhealthy lifestyle and perceived susceptibility of disease, overweight individuals are more likely to drop out of the course and little is known about how best to change sedentary behavior in adults.

While physical activity is required to achieve health benefits, it is important to recognize that the risk reduction for chronic diseases remains significantly greater for fitness than physical activity per se. Both high aerobic capacity (VO_{2peak}) and high skeletal muscle strength are associated with a lower prevalence of most chronic diseases than the recommended level of leisure-time physical activity. In analogy, our recent findings indicate that fitness (VO_{2peak}) was positively associated with health-related quality of life and negatively with depressive symptoms in obese women at elevated risk for gestational diabetes, while such an association was not found with leisure-time physical activity. Therefore, interventions should be optimized not only increasing physical activity but improving fitness, especially aerobic capacity, and muscle strength. We recognize the value of general guidelines and mass communications for physical activity, but they are effective only in some individuals highlighting the fact that over-simplifying approach lacks affectivity due to variability in the physiological system responses. Furthermore, a successful exercise program proposed at optimized intensity zones will not only increase effectiveness of but reduce dropouts from the intervention. These facts emphasize the importance of individualized approach in rehabilitation and prevention-oriented programs, and in decision making authorities, rather than group-based strategies.

2. PHYSICAL ACTIVITY, CARDIORESPIRATORY FITNESS, ANTHROPOMETRY, AND HEALTH

Physical activity has been defined to be “bodily movement produced by skeletal muscles that results in energy expenditure” (2018 Physical Activity Guidelines Advisory Committee, 1-799). “The term, physical activity, does not require or imply any specific aspect or quality of movement. The term includes all types, intensities, and domains. Although the term “physical activity” has been used often as a simpler description for moderate-to-vigorous-intensity forms of physical activity, given current interest and discussions about physical activity of intensities less than moderate-intensity (i.e., <3MET s), the term “physical activity” should instead be used when discussing the full range of intensities. More specific descriptors such as sedentary behaviour, light, moderate, vigorous, or moderate-to-vigorous should be used when talking about a specific range of intensities” (2018 Physical Activity Guidelines Advisory Committee).

“Exercise is physical activity that is planned, structured, repetitive, and designed to improve or maintain physical fitness, physical performance, or health. Exercise, like physical activity, covers all intensities. The word exercise, like the term physical activity, has been used often to mean moderate-to vigorous-intensity physical activity. However, it is preferable to specify the intensity when discussing or describing exercise” (2018 Physical Activity Guidelines Advisory Committee).

“Sedentary behaviour is any waking behaviour characterized by an energy expenditure 1.5 or fewer METs while sitting, reclining, or lying. Most office work, driving a car, and sitting while watching television are examples of sedentary behaviours” (2018 Physical Activity Guidelines Advisory Committee).

It has been proven that greater sedentary time is significantly associated for example with an increased risk of obesity, metabolic syndrome, diabetes, cardiovascular disease, mental, cognitive, and musculoskeletal disturbances, as well as cardiovascular and all-cause mortality. The mechanism is that physical inactivity leads to the build-up of visceral fat and therefore the activation of the oxidative stress/inflammation cascade. Silent low-grade inflammation has been associated with the development of the abovementioned health problems. The interplay between autonomic nervous system and inflammatory pathways has recently been suggested to modulate the inflammatory response (2018 Physical Activity Guidelines Advisory Committee)

A big problem is that the accumulation of harmful work stress, increased physical inactivity and inappropriate weight gain in the same individuals enhance the persistence of low-grade inflammation. Studies have shown that via these harmful health effects (e.g., depression, musculoskeletal disorders, metabolic and cardiovascular diseases) this vicious cycle may also reduce work capacity and shorten the working careers (2018 Physical Activity Guidelines Advisory Committee).

“Non-exercise physical activity is a concept that includes all physical activity that is not exercise. It has been used to mean several types and intensities of physical activity, mostly light intensity physical activity. Given its vagueness, however, clearer descriptions of the physical activity behaviour of interest are preferable” (2018 Physical Activity Guidelines Advisory Committee).

“Regular physical activity is proven to help prevent and manage nontransmissible diseases such as heart disease, stroke, diabetes, and several cancers. It also helps prevent hypertension, maintain healthy body weight, and can improve mental health, quality of life and well-being.” (WHO, 2006).

“Cardiorespiratory fitness (CRF) reflects the joined ability to transport oxygen from the atmosphere to the mitochondria to perform physical work. The primary measure of CRF is maximal oxygen uptake (VO_{2peak})” (Ross et al, 2016).

“Anthropometric measurements are non-invasive and helpful in assessing the nutritional status, identifying individuals at risk, monitoring the efficacy of a nutrition intervention and providing information about the body’s stores of fat and muscle” (Tchernof & Després J-P 2013).

Health is defined as “state of physical, mental and social well-being in which disease and infirmity are absent.” (WHO, 2006,). Health is the combination of all systems and their interactions within body. That´s why it must be studied at the whole organismal level (Ayres 2020).

2.1 Cardiorespiratory fitness and physical activity with health risk factors

Williams (2001) found following results in his meta-analysis from physical fitness and activity as separate disease risk factors:

1: “The risk of coronary heart disease (CHD) or cardiovascular disease (CVD) decreased linearly in association with increasing percentiles of physical activity”.

2: “In contrast to the linear reduction in CHD or CVD risk associated with increasing percentiles of physical activity, there is a swift decrease in risk occurring before the 25th percentile of the fitness distribution”.

3: “There is a significant difference in the risk reduction associated with being more physically active or more physically fit”.

Based on these findings Williams (2001) propose that cardiorespiratory fitness and physical activity have different association to CVD or CHD risk. Even if physical activity increases fitness and may be good treatment for the person, inactivity is not the main cause for being unfit when subclinical disease or genetics may be involved (figure 1).

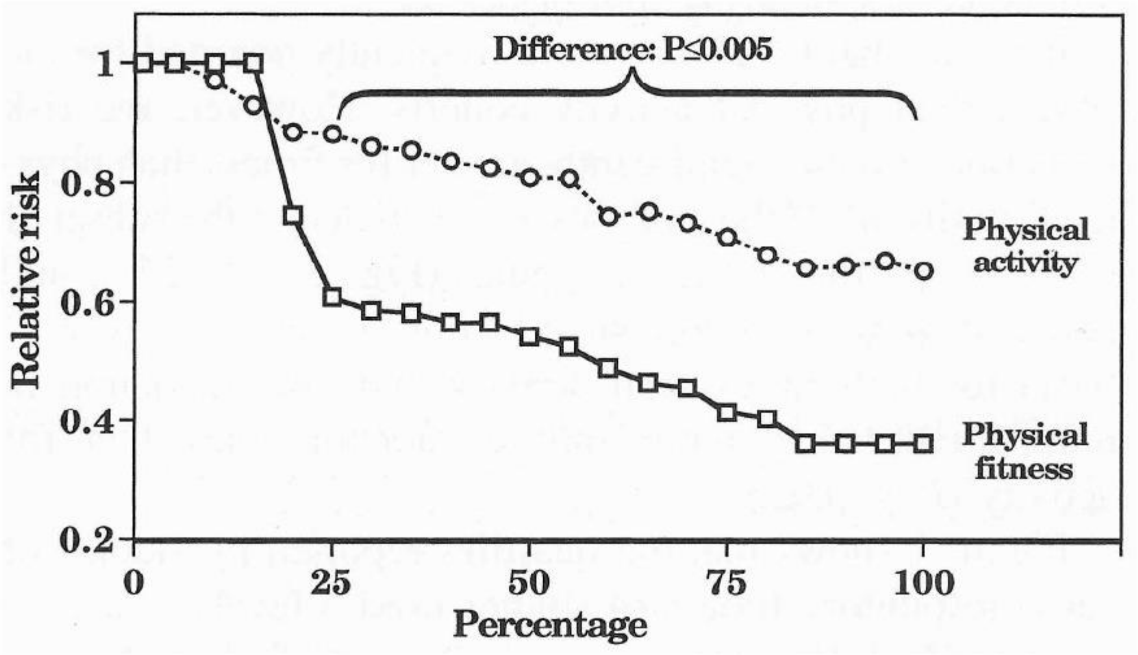


FIGURE 1. Relative risk for CHD or CVD in 8 physical fitness (317 908 person-years of follow up) and 30 physical activity cohorts (2 286 806 person-years of follow up) studies.

Tikkanen et al (2018) found in their longitudinal analyses that the inverse associations of grip strength and CRF with CHD and AF seen each category of genetic risk, showing that keeping good fitness can compensate for genetic risk of these diseases (figure 2).

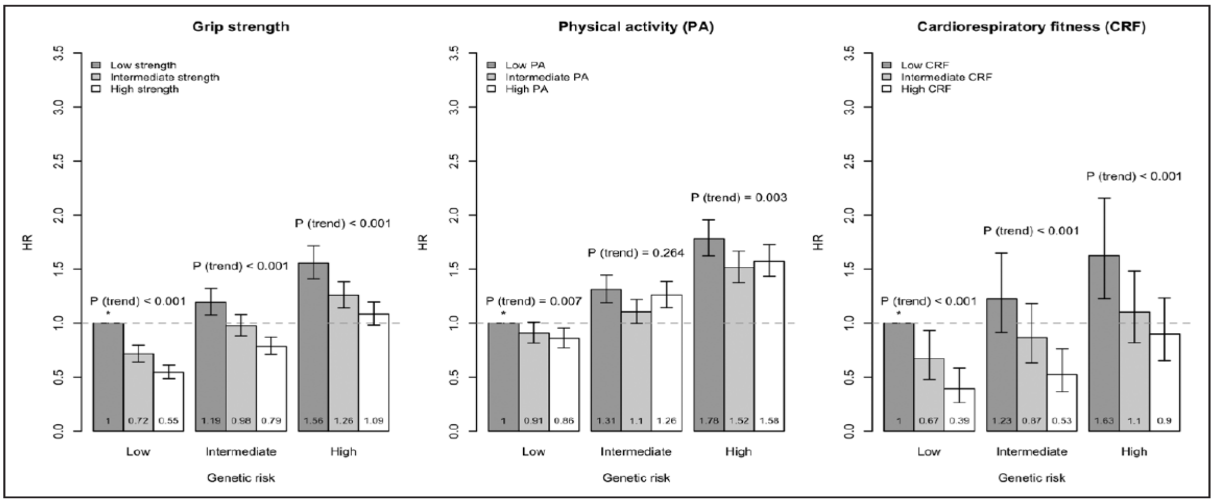


*FIGURE 2. Associations of grip strength, physical activity, and cardiorespiratory fitness with coronary heart disease by genetic risk. Hazard ratios with 95 confidence intervals for coronary heart disease (CHD) according to tertials of genetic risk and grip strength (left), physical activity (middle), and cardiorespiratory fitness (right). *Denotes the reference group (Tikkanen et al 2018).*

Cardiovascular fitness affects strongly to mortality in persons with Type 2 Diabetes. Evidence strongly supports reduced maximal aerobic capacity (15-20%) and slowing of the increase in $\dot{V}O_2$ at the onset of exercise. Both physical characteristics would forecast reduced performance at a given work rate, reflecting decreased exercise tolerance (Bauer et al 2007, Brandenburg et al 1999, Poitras et al 2018).

Many meta-analyses have shown that intensity is better interpreter than exercise volume of both the difference in glycated haemoglobin (HbA1c) and VO_{2peak}. In conclusion interventions with more forceful aerobic training interventions resulted in greater decreases in HbA1c, greater increase in VO_{2peak} and greater increase in insulin sensitivity (Zanusso et al 2010).

Some preliminary evidence has also been found for increased scores of perceived exertions (RPE) during submaximal exercise in unfit participants when monitoring for differences in relative exercise intensity at the same relative exercise intensity in their more fit subjects (Bauer et al 2007, Brandenburg et al 1999, Poitras et al 2018).

Those boundaries to exercise tolerance that are due to the cardiovascular system are therefore reason to the muscle oxygenation which is established by the transfer of O_2 from the lungs to the skeletal muscle capillaries, and the diffusive capacity for the movement of O_2 from the capillaries to the inside of the myocytes (Poitras et al 2018).

Measuring physical activity when persons have had a chronic disease for several years, it becomes exceedingly difficult to separate whether the disease and its effects on exercise tolerance led to greater inactivity, or if greater inactivity parallel with the disease refereed the exercise tolerance. Therefore, it may be so that persons with chronic diseases, have more risks to the effects of inactivity. The role of disease versus physical inactivity in exercise intolerance therefore remains to be determined, and investigators should not assume a disease-mediated phenomenon (Poitras et al 2018).

According to the research by Ross et al. (2016) about 50% of the difference in CRF is thought to be due to heritable factors; similarly, the effect of genetic factors to the response of CRF to physical activity estimates between 45% to 50%. These heritability estimations are alike in all the CVD risk factors (Ross et al 2016).

According to Poitras et al. (2018) cardiovascular support of exercising muscle can regulate submaximal muscle metabolic and contractile function and that is why directly influence the capacity for, and reached effort of, exercise, thus affecting to exercise easiness. Myers et al. (2015) showed in their study that physical activity and and cardiorespiratory fitness are influencing to cardiovascular disease risk (figure 3) (Myers et al 2015)

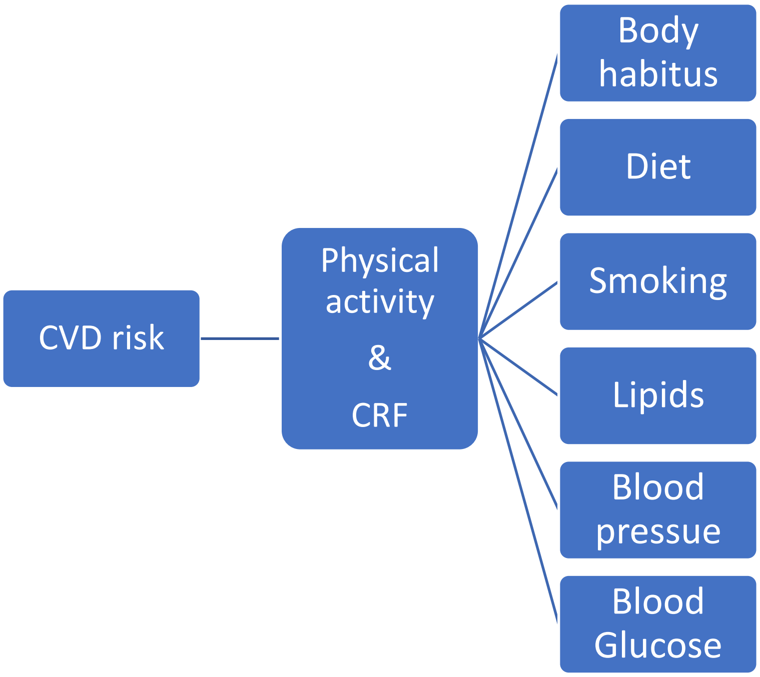


FIGURE 3. Physical activity and cardiorespiratory fitness are controlling cardiovascular disease risk (Myers et al 2015)

Potential Benefits of Cardiorespiratory Fitness on Prognosis according to Lavie et al 2015:

Physiological benefits

Reduced blood pressure
Improved heart rate variability
Increased myocardial infarction
Improved endothelial function
Reduced blood and plasma viscosity
Increased mitochondrial density
Reduced systemic inflammation

Improved insulin sensitivity
Decreased myocardial oxygen demands
Maintained lean mass
Reduced visceral adiposity
Increased capillary density
Improved mood and psychological stress
Improved sleep

Reduced risk of developing

Hypertension
Depression
Metabolic syndrome
Diabetes mellitus

Osteoporosis
Osteoarthrosis
Dementia and Alzheimer disease
Breast, colon, and other cancers

2.2 Anthropometry, cardiorespiratory fitness and, physical activity

The prevalence of overweight is increasing and is frightening as the excess fat mass typical for obesity increases the risk of cardiovascular and metabolic diseases (metabolic syndrome) (table 1) (Carbone et al 2019).

TABLE 1. Obesity phenotypes, fat mass, lean mass, and cardiorespiratory fitness. (Carbone et al 2019).

	Normal weight	**Athlete**	**Nonsarcopenic obese**	**Sarcopenic obese**
BMI (kg/m2)	18,5 -25	➢ 30	➢ 30	➢ 30
Fat mass	Normal	Decreased	Increased	Increased
Lean mass	Normal	Increased	Increased	Decreased
Cardiorespiratory fitness	Normal	Increased	Mild impairment?	Severe impairment?

Obesity is a powerful prognosticator of cardiovascular disease (CVD) even without other risk factors. After beginning of CVD in primary prevention the relationship between higher BMI and clinical results are not in lines. Obesity increases the risk for CVD in primary prevention and it has also been thought that excess body mass would also be dangerous in secondary prevention settings. This assumption is not correct as many researchers have verified a possibly protective effect of obesity when it exists together with CVD, so called “obesity paradox” (Carbone et al 2019). Patients with CV disease, higher BMI levels relate to better survival possibilities compared to those with lower levels. This phenomenon (“obesity paradox”) has been shown in many different CV conditions, like heart failure, hypertension, and coronary heart disease (Swift et al 2014).

According to Tchernof A & Després J-P (2013), the body mass index (BMI) is commonly used to evaluation of body fat as it is simple and cheap (table 2). The WHO classification is generally used to classify BMI. The percentage body fat (%BF) for a given BMI changes with age, and the amount of this change differs depending on sex, ethnicity, and individual differences. That is why BMI is not the most reliable measurement of body fat and metabolic risk.

TABLE 2. Health risk classification according to Body Mass Index (Tchernof A & Després J-P 2013).

Classification	**Body Mass Index category, kg/m2**	**Risk of developing health problems**
Underweight	<18,5	Increased
Normal weight	18,5 – 24,9	Least
Overweight		Increased
Obese	30,0 – 34,9	
Class 1	35,0 – 39,9	High
Class 2	40	Extremely high
Class 3		Extremely high

Tchernof A & Després J-P (2013) note that one limitation of the BMI relates to the metabolically obese, normal-weight (MONW) subject. These individuals, who have normal BMI values, nevertheless suffer from metabolic complications commonly found in obese subjects. Otherwise, metabolically healthy obese (MHO) peoples in different studies, who have a BMI over 30 kg/m^2 but are not categorized by insulin resistance or dyslipidaemia. These findings propose that high CVD risk may be noted even below the normal BMI (25 kg/m$^{2)}$. Essential element supporting the difference in CVD risk between MONW, and MHO persons is the amount of excess visceral adipose tissue. The research shows that most MONW persons with relatively low BMI likely have a considerable excess visceral adipose tissue, and many MHO persons with a high BMI do have much less visceral adipose tissue (Tchernof A, Després J-P 2013).

Another weakness of BMI found by the research conducted by Sedlemeier et al. (2021) is that it cannot separate between fat mass and fat free mass. Many researches have presented that the connection between BMI and total death rate could be opened into a J-shaped connection between fat mass index (fat mass/height^2) and death rate and a reverse J-shaped association between fat free mass index (fat-free mass/height^2) and death rate, with a tendency to separate of high fat-free mass values (Sedlemeier et al 2021).

Increased BMI is highly connected with an increase in fat mass likewise by an increase in fat free mass (FFM). FFM is often used to describe lean mass (LM) and skeletal muscle mass (SMM), though they all describe different body structures. FFM describes for most of the total body mass as it includes total body water (intra and extra cellular), bone, and SSM. The FFM without bone describes LM, which is the most used body structure sectioning to estimate SSM in individuals (Carbone et al 2019).

According to Sedlemeier et al. (2021) FM is linked to increased death risk, while fat-free mass defends against risk of death. These results point out that body composition offers significant prognostic information on an individual’s death risk. Compared with normal weight and fit persons, unfit persons have double the death regardless of BMI, whereas an obese but fit individual have comparable survival possibilities compared with normal weight persons (Lavie et al 2015)

The amount of fat mass (FM) has different effects on the cardiovascular system and metabolism, thus identifying its position is critical to identify persons with similar BMI and FM, but with different CVD risk profiles. Build-up of visceral FM is the biggest cardiometabolic risk factor. (Carbone et al 2019).

Increased lean mass (LM) in obese persons plays a significant role as it has been linked with improved long-term outcomes. Once hearth failure (HF) has been recognized, excess LM may allow a higher CRF, which is linked with better prognosis in HF and several other chronic diseases (Carbone et al 2019). Scott et al (2017) found in their study with sixteen overweight or obese women with or without polycystic ovary syndrome (PCOS) that VO_{2peak} was meaningfully negatively correlated with change in total body fat in women with PCOS, but not with those without PCOS.

Overweight and obese adults who follow public health recommendations-based exercise program without a nutritional plan including caloric limitation can suppose weight loss in range of no weight loss to around two kgs. However, the weight loss in individual level is highly heterogeneous. (table3) (Swift et al 2015). Efforts to persons who live a completely sedentary lifestyle involved in regular Physical Activity (PA), even if not meeting the target levels in Physical Activity Guidelines, is still especially important (Lavie et al 2015).

TABLE 3. Expected weight loss and possibly of producing clinically significant weight loss from different modalities of exercise training (Swift et al 2015)

Modality	**Weight Loss**	**Clinically significant weight loss**
Pedometer-based step goal	Range: 0 to 1 kg	Unlikely
Aerobic exercise only	Range: 0 to 2 kg	Possible, but only with extremely high exercise volumes
Resistance training only	None	Unlikely
Aerobic and resistance training only	Range: 0 to 2 kg	Possible, but only with extremely high volumes of aerobic exercise training
Caloric restriction combined with aerobic exercise training	Range: -9 to - 13 kg	Possible

2.3 Physical activity, and cardiorespiratory fitness in overweight and obese subjects

Exercise interventions can be created using the FITT principle: Frequency, Intensity, Time (duration of exercise), and Type (mode of exercise). Of these variables, the one of most concern for improving VO_{2peak} is the intensity (figure 4.) (Swain 2005).

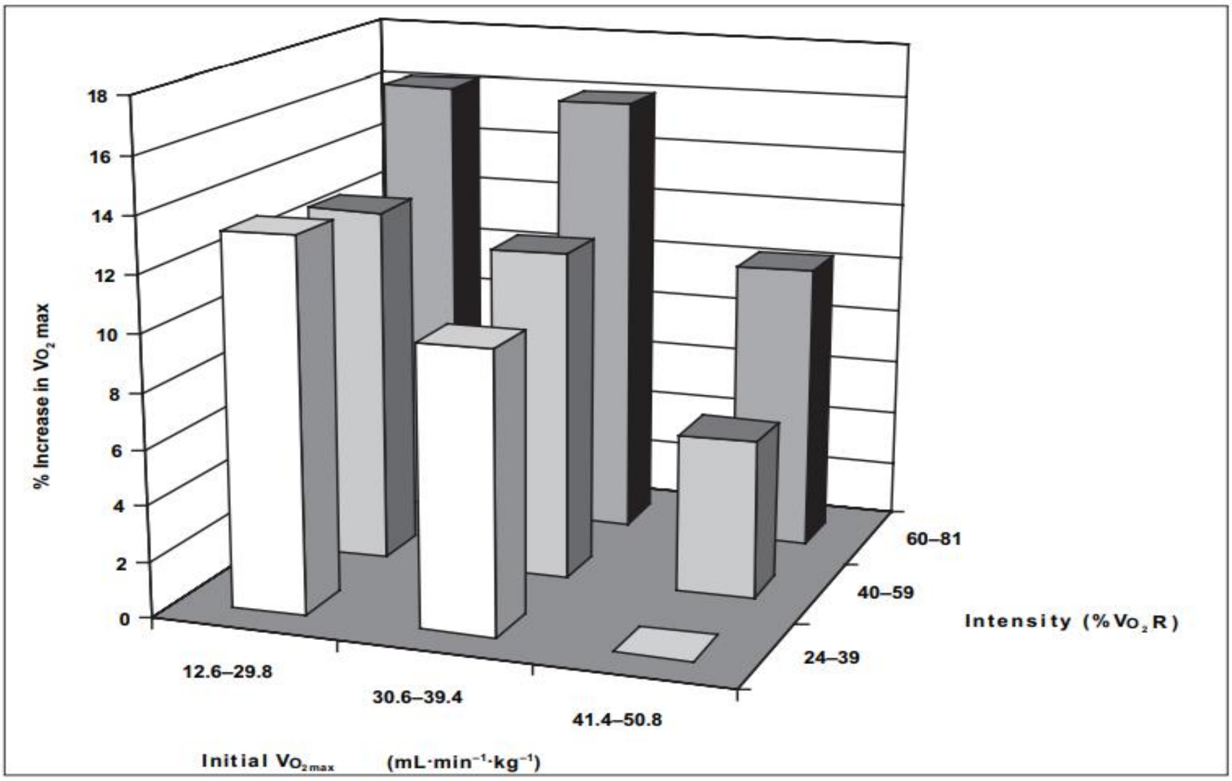


FIGURE 4. The interaction of initial fitness and exercise training intensity on the improvement in aerobic capacity. Higher intensities are more effective than lower intensities, and more fit individuals experience less improvement than lower fit individuals at any given intensity (VO_2R = maximal oxygen consumption reserve) (Swain 2005).

According to Swain (2005) physical training programs should be planned to achieve maximal increases in VO_{2peak}, being sure that there are no limitations to more vigorous training. Vigorous exercise (60-80% VO_2R or HR reserve) is more effective in increasing VO_{2peak}, than is moderate intensity exercise (40-59% VO_2R or HR reserve), even when the length of exercise is modified so that the same number of calories is spent. Whereas most training interventions apply continuous exercise, such as 20-60 min at a moderate or vigorous intensity, interval training applying 3-min bouts at VO_{2peak} can be the most effective way in increasing aerobic capacity. Initially inactive persons should start with moderate intensity, which is effective in improving their VO_{2peak} and move up to higher intensities after a time of adaptation. (Swain 2005).

De Prada et al. (2019) studied if exercise intensity was comparative to ventilatory thresholds (VTs) estimates the improvements in cardiorespiratory fitness (CRF) in middle-age sedentary persons with overweight. They found that VO_{2peak} improvement was independent of training intensity comparative to ventilatory thresholds, whereas the evaluation of submaximal CRF parameters (ventilatory threshold) depended on training intensity. The largest VO_2

improvement was measured at VT1. VO_2 increased at VT1 and VT2 in both groups, OVER group subjects showed higher increasing at VT1. Subjects who trained over VT1, showed bigger increasing of VO_2 than those who trained under VT1, while VO_{2peak} improved equally in both groups. (De Prada et al 2019).

Chávez-Guevara et al (2020) found in their meta-analysis study a minor VO_{2peak} increase (MD = 2.96 mL·kg^{-1} ·min^{-1}, 95% CI: 2.01–3.90 mL·kg^{-1} ·min^{-1}) after 8 to 16 weeks of maximal fat oxidation intensity (FMT). This is explained by the increase of absolute oxygen uptake (0.05–0.16 L·min^{-1}) and not by body weight decrease only. Bodyweight decreased between 1,88-6,52% from baseline and FFM remained unchanged. The noted change represents a mean increase of 10% in participants CRF and is in line with results by Murphy et al. (2007) (2.73 mL·kg^{-1} ·min^{-1}). Such increase is linked with a decrease in diastolic blood pressure. Wang et al. (2015) showed that 10% increase of CRF after 10 weeks of FMT is enough to reduce systolic blood pressure (~13 mmHg) and improve stroke volume (~5 mL) and ejection fraction (~4.6%) in sedentary individuals. Based on these studies, FMT seems to improve CRF and reduce cardiovascular risk in obese and overweight patients, at least in the beginning of physical training interventions (Chávez-Guevara et al, 2020).

As Mondal and Mihsra (2017) found, there is higher correlation coefficient of fat% and VO_{2peak} compared to that of BMI and VO_{2peak}. This signifies obesity in terms of fat% is a better parameter than BMI for likelihood of low cardiorespiratory functional status. Decrease in body fat% can help in relative increase in FFM and increase in VO_{2peak}. (figure5 and 6) (Mondal & Mishra 2017)

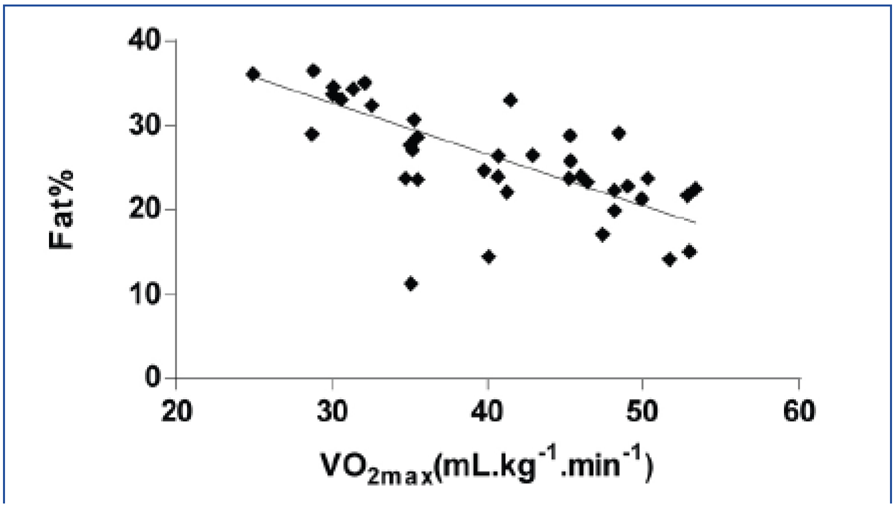


FIGURE 5. Relationship between fat% and VO_{2peak} *(R2 = 0,5633, F= 67,08, p= <0,001, equation: Y= -0,6090*X +50,96) (Mondal & Mishra 2017)*

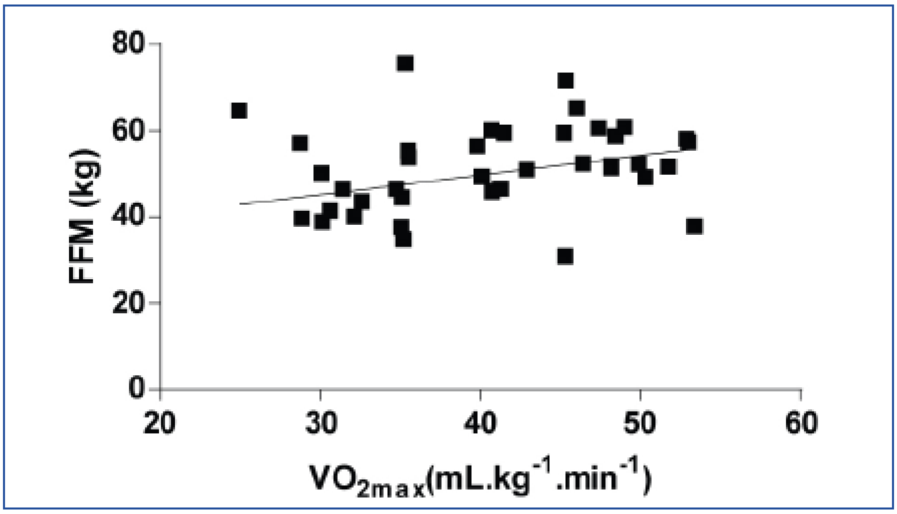


FIGURE 6. Relationship between FFM and $VO_{2\,max}$ *(R2 = 0,1389, F= 8.390, p= 0,0055, Equation: Y=0,4542*X= +31,54) (Mondal & Mishra 2017)*

As Gaesser and Angadi below summarises in their review (2021) motivation for a weight-neutral approach for obesity treatment should move to changing the attention from weight loss to increasing physical activity and improving cardiorespiratory fitness:

- the mortality risk linked with obesity is attenuated or eliminated by moderate-to-high levels of cardiorespiratory fitness (CRF) or physical activity (PA)
- most cardiometabolic risk markers associated with obesity can be improved with exercise training independent of weight loss and by magnitude like that observed with weight-loss programs
- weight loss, even if intentional, is not consistently associated with lower mortality risk
- increases in CRF or PA are consistently associated with greater reductions in mortality risk than is intentional weight loss
- weight cycling is associated with numerous adverse health outcomes including increased mortality

3. CHRONIC TRAINING ADAPTATIONS AND CARDIORESPIRATORY FITNESS

Maximal exercise capacity is determined by many factors, including maximal ability to transport O_2 to the muscle mitochondria and to use this O_2 for ATP generation (VO_{2peak}) (Wagner 2011). The O_2 transport and utilization system is an in-series system (figure 7) in which every component is important to overall system throughput of O_2. There are four crucial steps in the transport pathway (ventilation, alveolar/capillary diffusion, circulation, and muscle diffusion), which all have the power to affect VO_{2peak} – there is no limiting factor. Changes in any of the steps affects the function of the others (Wagner 2011).

$VO_{2\ peak}$ may be set by metabolic limits, apparently seen in unfit humans with low peak VO_2 values, providing extra O_2 does not improve VO_2 and reducing FIO_2 moderately does not diminish VO_{2peak}. $VO_{2\ peak}$ may also be set by O_2 transport limits. This seems to be the case for fit subjects, because providing extra O_2 does not improve VO_2. Under such conditions, all elements of the O_2 transport pathway act to limit VO_{2peak} in an integrated way (Wagner 2000).

Increase of cardiac output (CO) is the central factor of maximal oxygen consumption (VO_2), as defined by the Fick equation:

$VO_2 = CO \times (a\text{-}v)\ O_2diff.$

where a-vO_2 difference is the arteriovenous oxygen difference. At rest, CO is similar at ≈5 l/min. At maximal exercise, CO varies from ≈ 20 l/min in healthy untrained persons to ≈ 40 l/min in elite aerobic athletes. This wide variability in CO in part explains the wide range in maximal VO_2 (Lavie et al 2015).

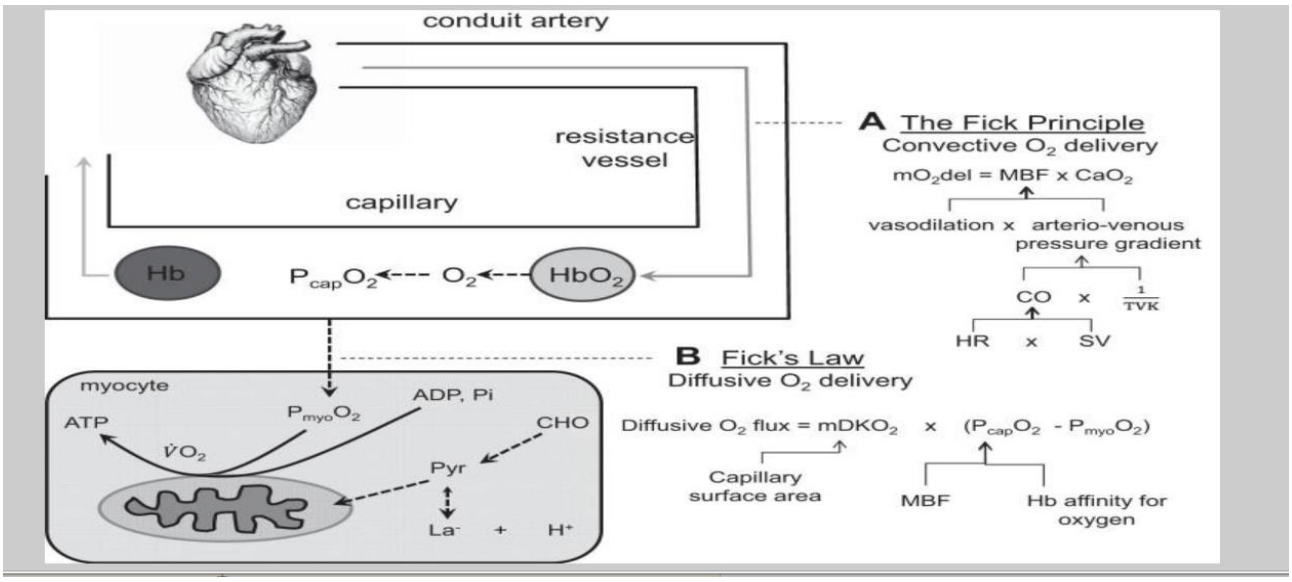


FIGURE 7. The Fick principle and Fick`s law

Overall, The Fick principle describes the relationship between muscle $\dot{V}O_2$, oxygen delivery (mO_2del), and oxygen extraction (arteriovenous O_2 difference). Muscle oxygen delivery is the product of muscle blood flow (MBF) and arterial oxygen content (Ca_{O2}), and it establishes the partial pressure of oxygen in the capillaries ($PcapO_2$; the driving pressure for diffusion of O_2 from the capillaries to the inside of the myocytes). Thus, it interacts with $mDKO_2$ to determine the diffusive flux of oxygen into the myocyte according to Fick's law and thereby establishes $PmyoO_2$ at a given $\dot{V}O_{2peak}$. The three main chronic responses of physical exercise are: metabolic flexibility, cardiac remodelling, and angiogenesis (Wu et al 2019)

The focus in this study will be in $\dot{V}O_2$ and not in oxygen delivery and oxygen extraction.

3.1 Physical performance

Sedentary lifestyle or lacking physical activity is not only connected with increase in body fat%, but it is also a reason for the decrease in total muscle mass. The more the muscle mass involved in exercise, the greater is the contribution of muscle pump to venous return. Therefore, increase in muscle mass supports to get an increased cardiac output. The positive correlation between FFM and VO_{2peak} found in studies (Morinder et al 2009, Goran et al 2000, Vsetulova et al 2004, Mondal & Mishra 2017) shows that an increase in FFM may be responsible for increased VO_{2peak} (ml / kg FFM / min) (Mondal & Mishra 2017).

Deconditioning:

Subject deconditioning is apparent from the following responses:

- low VO_2 measured in ml/kg/min (relative), despite normal VO_2 measured in l/min (absolute)
- low VO_2 with the absence of other abnormal responses
- low visceral adipose tissue
- exaggerated heart rate response

Obesity:

- increased VO_2/work slope
- indexed peak VO_2 less (ml/kg/min) than predicted, absolute VO_2 (l/min) normal or greater than predicted, oxygen indexed to lean body mass normal or greater than predicted (Umapathl & Nguyen 2020).

$VO2_{peakffm}$ is better estimation value in healthy adults than $VO_{2peaktbw}$ ($ml/kg^{-1}/min^{-1}$). That is why physiological benefit of $VO_{2peakffm}$ as a degree of CRF is obvious because it is not only the most precise measure of CRF as it relates to exercise performance, but also the greatest way to present CRF as it relates health (Impoden et al 2020).

3.2 Maximal oxygen uptake (VO_{2peak})

VO_2 is measured in litres or millilitres of oxygen per minute or in millilitres per kilogram of body weight per minute and is defined by the Fick principle. Maximal oxygen uptake ($VO_{2\,max}$) is a parameter telling the maximal amount of energy available by aerobic metabolism per unit of time (aerobic power) at peak incremental exercise and is defined as the highest volume of VO_2, achieved at presumed maximal effort during an incremental CPET (Mezzani 2017).

For young, healthy subjects that are used to pushing themselves to exhaustion while cycling or running, the incremental/ramp cardiopulmonary exercise test yields a highly reproducible VO_{2max} with different exercise test protocols. Nevertheless, this may not be guaranteed with exercise-naïve, unmotivated, and/or clinical individuals. To eliminate this uncertainty, scientists have been reporting the term VO_{2peak} as the highest VO_2 value achieved on a given test (Poole & Jones 2017).

As Levine (2008) makes a conclusion in his study: $VO_{2\ peak}$ is the most crucial factor of endurance performance, which represents a true parametric measure of cardiorespiratory capacity for a person at a given degree of fitness and oxygen availability. VO_{2peak} is a value telling the maximal amount of energy available by aerobic metabolism per unit of time (aerobic power) at peak incremental exercise and is defined as the highest volume of VO_2 averaged over a 20- to 30- second period, reached at supposed maximal effort during an incremental cardiopulmonary exercise test. (Mezzani 2017).

In this study, VO_{2peak} and VO_2 at ventilatory thresholds will be used as indicators of cardiorespiratory fitness.

VO_{2peak} decreases on average by 10% per decade after the age of thirty, because of decreasing maximal heart rate, stroke volume, blood flow to skeletal muscle, and skeletal muscle aerobic potential with decreasing age. VO_{2peak} is 10 to 20% greater in men than in women of at the same age, because of higher haemoglobin concentration and greater muscle mass and stroke volume in men (Mezzani 2017).

Physiological issues that can limit VO_{2peak} are: 1) the pulmonary diffusing capacity, 2) maximal cardiac output, 3) oxygen carrying capacity of the blood, and 4) skeletal muscle characteristics. The first three factors can be classified as “central” factors; the fourth is called a “peripheral” factor (Bassett & Howley 2000): There are wide personal variances in the increases in VO_{2peak} even when adults are participating to a standardized and fully monitored exercise training interventions. The assessed heritability of the trainability of VO_{2peak} can be 47% (figure 8) (Sarzynski et al 2017).

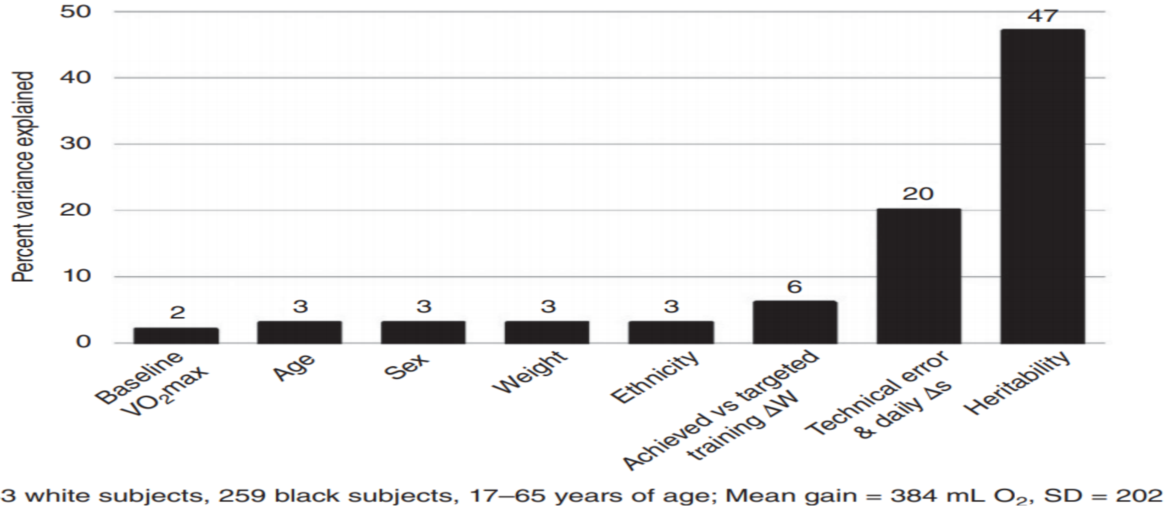


FIGURE 8. A summary of the correlates of the gains in VO_{2peak} in the HERITAGE Family Study. The contributions of various correlates of percentage variance for in VO_{2peak} response (Sarzynski et al 2017).

Wagner (2021) observed that VO_{2peak} among people was higher when they did more moderate- and vigorous- intensity physical activity. Time of physical activity made at light, moderate and vigorous intensities together with age and sex explain 67% of the change in VO_{2peak} (ml/kg/min) values. Activities made at vigorous intensity had a strong connection with CRF, as shown in figure 9. A relevant difference in VO_{2peak} (an increase of > 1 ml/kg/min) was observed with as low as 4 minutes of additional vigorous physical activity per day. 1-MET higher CRF (3,5 ml/kg/min), which corresponds to an appr. fifteen percent lower incidence of myocardial infarction was associated with 13 minutes of additional vigorous physical activity per day (Wagner 2021).

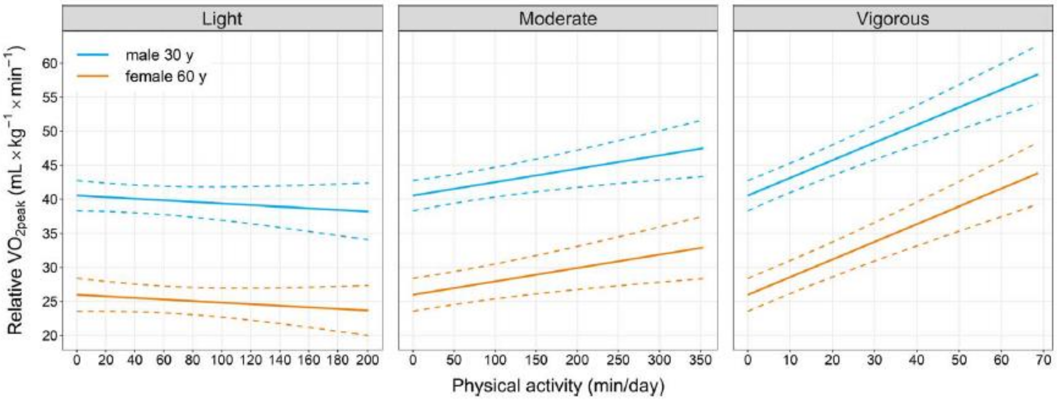


FIGURE 9. Association of LPA, MPA and VPA and relative VO_{2peak}. To visualize association between VO_{2peak} and levels of LPS. MPA and VPA, exemplary values for independent variables age and sex were inserted into the linear regression (Wagner 2021)

Submaximal performance – related CPET parameters (VO_2 at VT) showed comparable results with MPA and VPA as VO_{2peak}. These results indicates that LPA was too low stimulus to increase oxygen uptake at submaximal level (VT1) or improve oxygen uptake efficiency (Wagner 2021). Like other studies of exercise testing, Salvadori et al (2008) found that fatigue was reached at power outputs not significantly different between obese and lean subjects and VT was significantly lower in obese group. VO_2 was significantly higher in obese subjects during exercise and similar at rest, when overcoming VT and at the respective peak output. At exhaustion, maximum oxygen uptake was 94 and 83% of theoretical maximal VO_2 in lean and obese subjects, respectively. VCO_2 was higher at in the obese subjects at every power output.

Ross et al (2016) noted in their research that VO_{2max} quantifies the functional capacity of a person. The process according to Ross et al (2016) is hooked on a processes that include pulmonary ventilation and diffusion, right and left ventricular function (both systole and diastole), ventricular-arterial coupling, the ability of the vasculature to accommodate and efficiently transport blood from the heart to precisely match oxygen requirements, and the ability of the muscle cells to receive and use the oxygen and nutrients delivered by the blood, as well as to communicate these metabolic demands to the cardiovascular control centre. The research shows that, CRF is straight connected to the integrated function of numerous systems, and it is therefore seen as a reflection of total body health (Ross et al, 2016).

3.3 Ventilatory thresholds

Gas exchange analysis by V-slope method has been designated to detect the AT involves the analysis of the behaviour of VCO_2 as a function of VO_2 during progressive exercise tests when exceeding the LT is attended by the buffering of lactic acid by (HCO3-) with a consequent increase in VCO_2 (Beaver et al 1986). This results in a transition in the relationship between the VCO_2 and VO_2, which is the fundamental element in all methods of anaerobic threshold detection by gas exchange. VO_2 is used as the independent variable because it is the direct index of metabolism. This AT detection procedure have been termed the V-slope method since it is based on analysing the slopes of gas (O_2 and CO_2) volume curves (Beaver et al 1986).

After an initial adjustment of the CO_2 stores at the start of the incremental work phase, CO_2 delivered to the lungs rises linearly with O_2 uptake up to the VT1. Above the AT1, CO_2 output increases more steeply relative to O_2 uptake, as shown in figure 10A, which is a plot of VCO_2 vs VO_2. The two dashed regression lines in figure 10A represent the two linear portions of the curve that join at the point where VCO_2 clearly begins to increase more rapidly (Beaver et al 1986).

Figure 10B is a plot of V_E vs VCO_2, showing a break point marked by the intersection of the dashed regression lines that represent the two linear segments above and below this point. This point of increased slope marks the start of respiratory compensation (RC) for metabolic acidosis, below which V_E is tightly coupled to VCO_2 but above which V_E rises more rapidly in phase of relative hyperventilation. In this phase, the behaviour of VCO_2 no longer solely reflects metabolic and buffering events in the tissues. In figure 10A, the VCO_2 vs VO_2 curve is seen to be linear between the AT and RC points. The AT is located by defining the intersection between this segment and the linear segment of the curve at the lower work rates (Beaver et al 1986).

Figure 10C shows V_E plotted against VO_2. It has been proposed that a three-segment linear regression model be fitted to the V_E/-VO_2 relationship to estimate the location of AT (Beaver et al 1986).

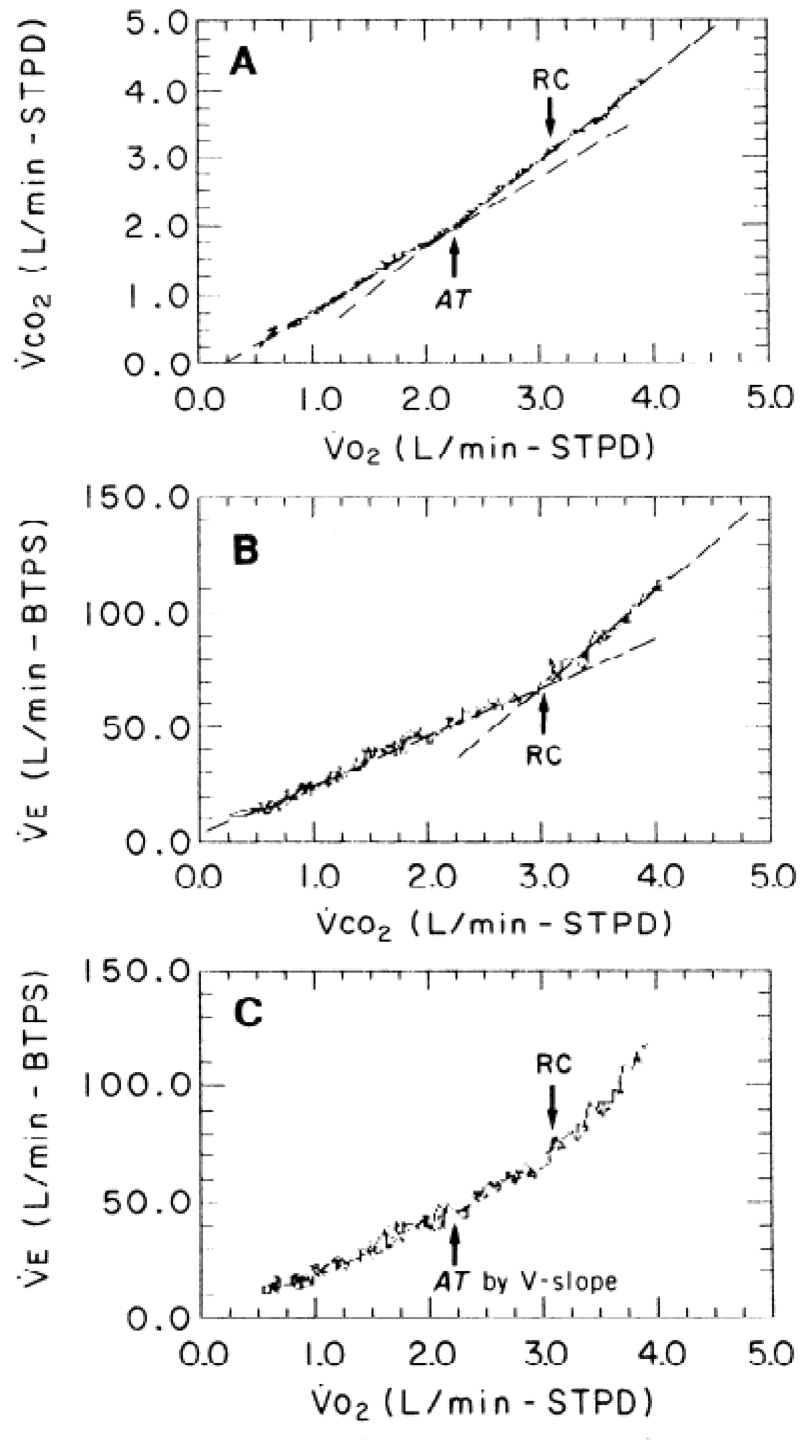


FIGURE 10. A. CO_2 production (VCO_2) vs O_2 uptake (VO_2) from fig x, showing regression lines for detecting inflection point (AT point). B. minute ventilation (V_E) vs VCO_2, showing regression lines for detecting inflection point (RC point). C. V_E vs VO_2, showing AT and RC points derived separately by analysing Fig 16A and B (Beaver et al 1986).

As Mezzani (2017) notes, a multitude of different terms (AT, RC) are found in the literature describing the two thresholds, the term “ventilatory” thresholds (VT1, VT2) is preferred. This is because those two transitions are spotted using incremental exercise- induced changes in ventilation-related parameters and not only in direct descriptors of metabolic homeostasis alteration (lactic acid) (figure 11) (Mezzani 2017).

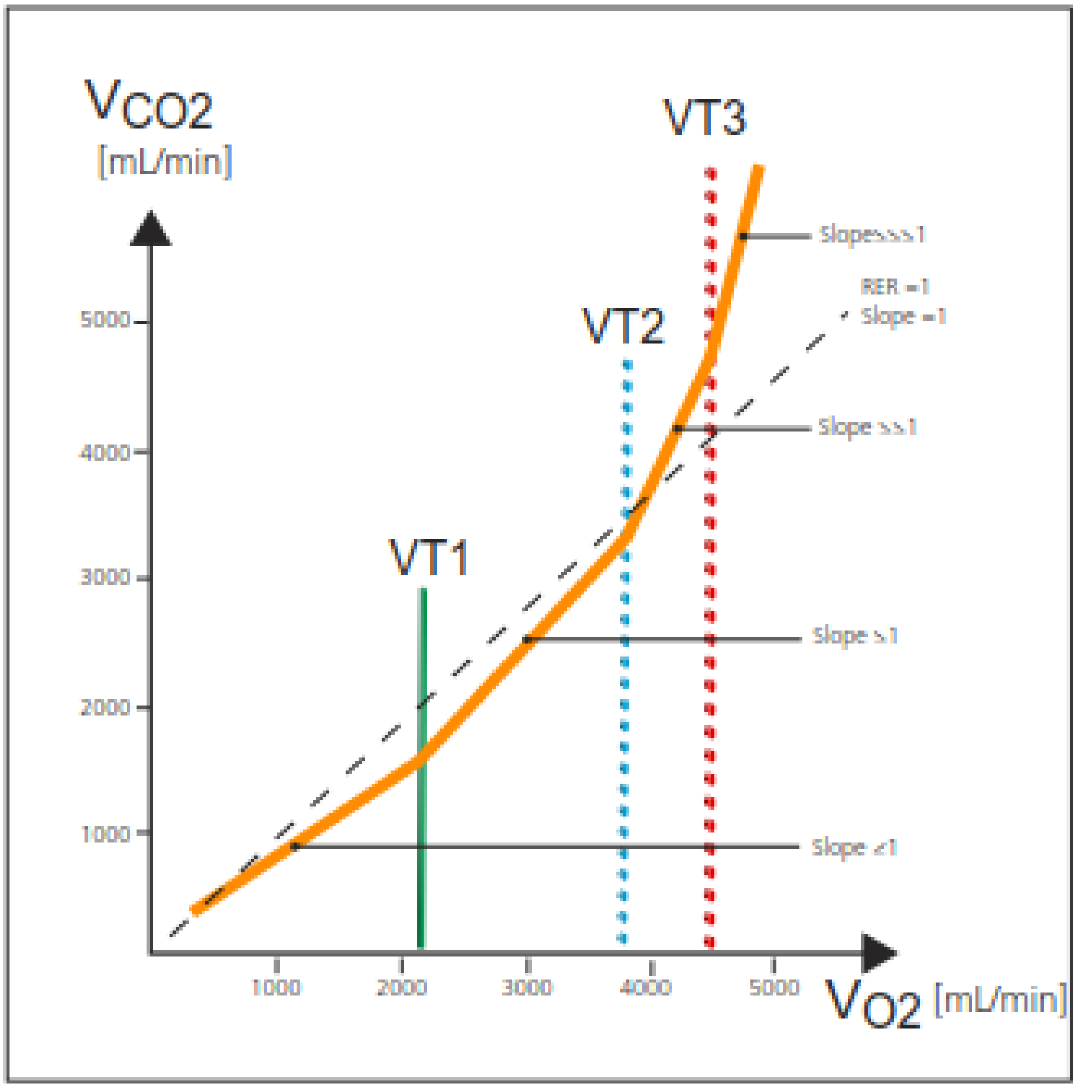


FIGURE 11. V-Slope graphic illustrating the emergence of the break points. CareFusion. Special Edition Cardiopulmonary Exercise Testing, 2017, Page 34

According to Poole et al. (2020) the gas exchange threshold (GET) is defined as the metabolic rate at which excess CO_2 is evolved proportional to the rate which muscle and blood (bicarbonate) decrease, consequent to buffering of a metabolic acidosis, and which derives from non-hyperventilation mechanism. GET is identified by an increase in the VCO_2 / VO_2 relationship (the V-slope plot) with evidence of absence of a frank hyperventilation. GET happens proximal to the increase of arterial blood. (Poole et al. 2020).

4. GENERAL GUIDELINES VS PERSONALIZED EXERCISE PRESCRIPTION

4.1 The physical activity guidelines

The Physical Activity Guidelines to Americans 2018 conducted a systematic review of the science supporting physical activity and health. Key guidelines are provided for all people in the United States. The main audience for the PAG is health professionals and policy makers, but the document is also useful to individuals (Piercy et al 2018).

Key guidelines to adults according to research by Piercy et al (2018):

"Adults should move more and sit less throughout the day. Some physical activity is better than none. Adults who sit less and do any amount of moderate-to-vigorous activity gain some health benefits."

"For substantial health benefits, adults should do at least 150 minutes to 300 minutes a week of moderate-intensity, or 75 minutes to 150 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate and vigorous-intensity aerobic activity. Preferably, aerobic activity should be spread throughout the week."

"Additional health benefits are gained by doing physical activity beyond the equivalent of 300 minutes of moderate-intensity physical activity a week."

"Adults should also do muscle-strengthening activities of moderate or greater intensity that involve all major muscle groups on two or more days a week, as these activities provide additional health benefits." (table4)

Physical activity Guidelines and cardiorespiratory fitness (Arena R et al. 2018)

TABLE 4. American College of Sports Medicine Position stand (Garber et al. 2011)

How much to move?

Moderate intensity physical activity for health	At least 2h 30 min / week	Everything which increase Your heartbeat is good	Physical activity is moderate when You can speak at the same time
Vigorous intensity physical activity for physical performance	At least 1h 15min / week	You get the same health benefits by increasing intensity	Physical activity is vigorous if You cannot speak at the same time
Muscle-strengthening activities	At least twice a week	Activate all major muscle groups and challenge Your balance	Choose Your own way: stair walking, heavy gardening works, group exercising, gym…

4.2 Individualized exercise training interventions

Many studies have recommended a more individualized training interventions using ventilatory thresholds to personalize an exercise program based on personal metabolic responses, and thus increase the likely advantages of regular physical activity. VO_{2peak} has been mostly used to prescribe exercise intensity and evaluate training responses. VO_{2peak} value does not always indicate a maximal value for aerobic fitness (Weatherwax et al 2018).

Weatherwax et al (2018) found in their study that after 12 weeks aerobic exercise training based on individualized exercise interventions using ventilatory threshold measures, had a bigger effect on the training response compared with an approach using hearth rate reserve (HHR). They also noted that training intensity prescribed with the use of ventilatory thresholds takes into consideration individual metabolic differences, which are ignored when using relative percent methods ($\%VO_{2peak}$, $\%VO_2R$, HRR). (Weatherwax et al 2018).

Noticeably big result of training intensity prescription method on the incidence of VO_{2peak} responders occurred with the individualized group producing 100% responsiveness, whereas the standardized group had a 60% incidence response (figure 12). At the group level, there was a statistically significant positive change in CRF but no difference between groups. Although, at the individual level, all subjects in the individualized group improved VO_{2peak} greater than the founded responder threshold of 4,7%, while 8 of 20 participants in standardized group failed to reach that level. Even if not statistically significant, there was a 48% greater improvement in the percent change in VO_{2peak} at the end of program. Training responsiveness is an individual and not a group phenomenon, in spite all criteria for responsiveness and exercise interventions have focused on group factors (Weatherwax et al 2018).

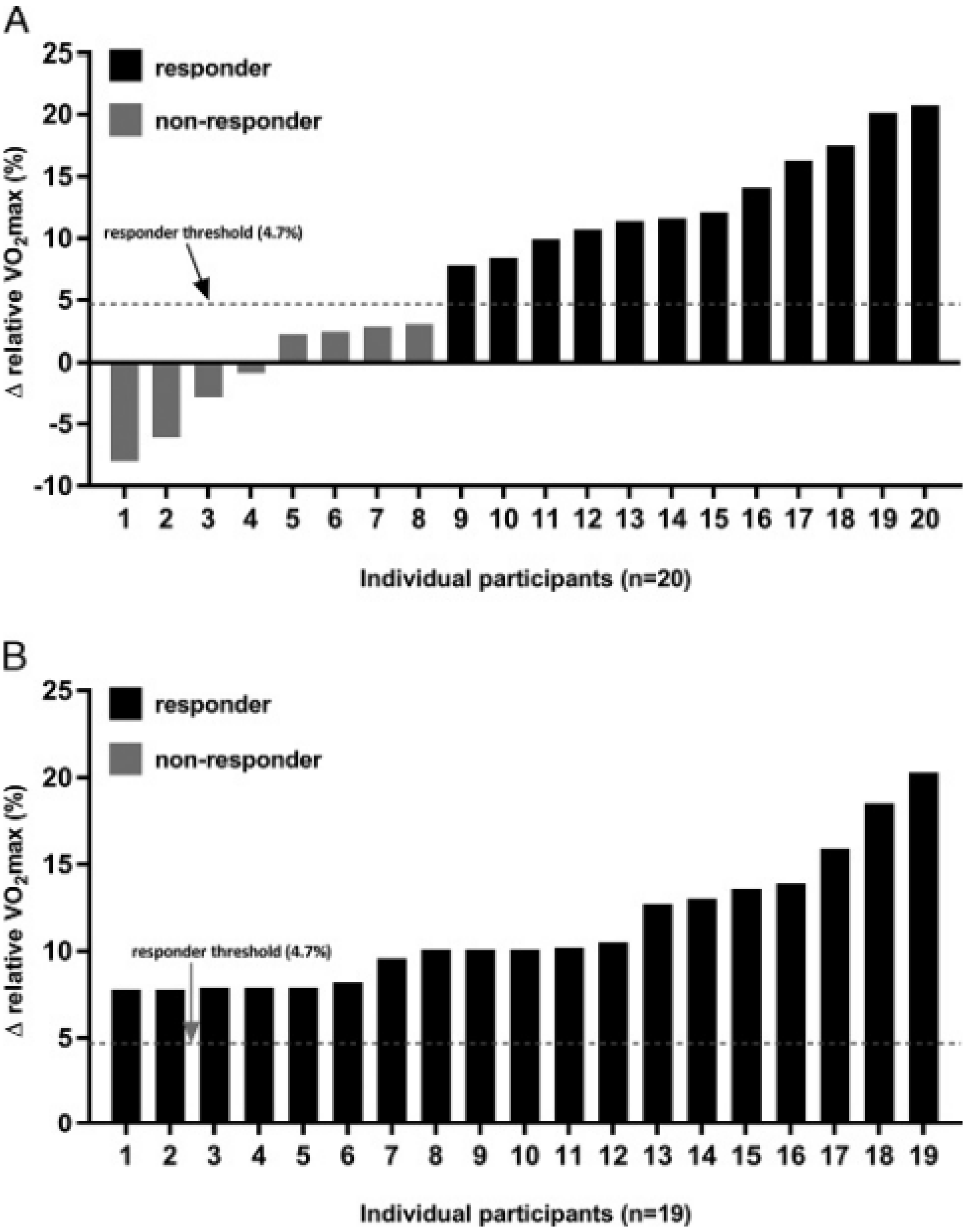


FIGURE 12. Variability in relative $VO_{2\ max}$ responsiveness (%change) to 12 weeks of standardized (A) and individualized (B) exercise training. The dashed line indicates the minimum change ($\Delta > 4,7\%$) required to be considered a meaningful adaption in VO_{2peak} (ml/kg/min) (Weatherwax et al 2018).

The level of exercise training (ET) generating cardiac adaptations in obviously healthy persons is influenced by the interaction of several things, including age, sex, genetics, previous training status, mode of ET, and ET volume. Therefore an accurate prediction of the degree of cardiac adaptations expected with a given aerobic ET program for a given individual is not feasible. Aerobic ET, performed within general ET prescription parameters, positively alters cardiac morphology and physical performance. These adaptations lead to increased CO during exercise, enabling a higher maximal VO_2 after training (Lavie et al 2015).

4.3 Technology based online tools to follow physical activity and exercise training

Physical activity promotion makes an important impact to the global public health agenda, through programs that target a diverse range of diseases, in diverse groups, settings, and countries. Technical innovations can give important possibilities for physical activity promotors to reach peoples. Measuring and influencing physical activity through a mobile app has been related to weight reduction as well as improvements in other cardiovascular risk factors, and quality of life (Bort-Roig et al 2014).

Research by Bort-Roig et al. (2014) notes that physical activity profiles, real-time feedback, social networking, expert consultation, and goal setting are key features that facilitate PA engagement. There are also features that limits engagement, such as disruptive reminders and audio signals, text messaging, and competition-based approaches (Bort-Roig et al 2014).

Dallinga et al (2015) find in their study, that mobile app was positively related to physical activity, feeling healthier, changing lifestyle and self-image. The use of mobile apps was positively related to encouraging others to become active. In addition app used by longer distance runners was positively related to feeling more energetic, eating healthier and maintaining sport behaviour (Dallinga et al 2015).

They also noticed that the intention to maintain the running training was higher for the app users, therefore app use may assist in decreasing drop-out of training and inspiring physical activity. This was an interesting finding, because apps were more often used by overweight participants (Dallinga et al 2015).

Barkley et al. (2020) noticed that individuals with greater motivation to physical activation and exercising seeks out things which may encourage their training character, such as: exercise equipment, membership to fitness centres, and fitness apps. Because training character mediated in their study to the relationship between fitness app use and physical activity, identity may be the predominant factor in influencing whether a person will self-select to use fitness apps and/or be physically active (Barkley et al 2020).

Loyalty to mobile app use can decrease over time with some users. Participants who benefit from and continue to use mobile apps may have had greater training character compared to those who did not benefit from app use. Therefore apps may work better for those characterize as exercisers or, who during the process, experience an increase in training identity (Barkley et al 2020).

Important for successful fitness apps is that they are theory-based, validated, include interactive components with personalized planning, tracking and feedback, provide possibilities for peer support and integrate promises given by music to boost motivation and adherence in exercising. Music is often used during exercise for motivational purposes, to balance emotional and physical exhaustion, and to improve performance. Many new studies haves implied physiologic evidence for the role of music in increasing exercise performance, improving the lipid profile, and facilitating post-exercise recovery (Cotter et al 2014, Rabin et al 2011, Silberg et al 1997, Yamasaki et al 2012).

5. RESEARCH QUESTIONS

The goal of MoMaMo! is to develop truly individually tailored multidisciplinary interventions for at-risk individuals. Seeking to develop an operational model to guide initiation and progress of an effective lifestyle intervention focusing on promoting citizen engagement in health and wellbeing by prevention and treatment of overweight/obesity and diseases that are due to inactive, sedentary lifestyle

Specified study questions and hypothesis:

1. Is a 3-month exercise intervention effective in improving anthropometry (weight, BMI, FFM, fat%) in overweight and obese subjects? Are personalized and highly personalized technology-assisted exercise interventions (Group 2 and 3) more effective than general guidelines (Group 1)?

- Hypothesis: Changes in anthropometry with personalized technology-assisted exercise interventions (Group 2 and 3) are more effective than general guidelines (Group 1)

2. Is a 3-month exercise intervention effective in improving cardiorespiratory fitness (VO_{2peak}, VT1, VT2) and exercise performance (W) in overweight and obese subjects? Are personalized and highly personalized technology-assisted exercise interventions (Group 2 and 3) more effective than general guidelines (Group 1)?

- Hypothesis: Changes in Cardiorespiratory fitness exercise performance values with personalized technology-assisted exercise interventions (Group 2 and 3) are more effective than general guidelines (Group 1)

3. Is a 3-month exercise intervention effective in improving Cardiorespiratory fitness at a given moderate workload (60W female, 80W male) in overweight and obese subjects?

- Hypothesis: Effects of 3-month exercise intervention are not limited to hard and/or severe exercise intensity but improvements can also be seen at a given moderate exercise intensity

4. Do expected changes in anthropometry and cardiorespiratory fitness occur simultaneously, or can changes be found independently of each other?

- Hypothesis: Changes in anthropometry (weight, BMI, BF, and/or FFM) and Cardiorespiratory fitness (VO_{2peak}, VT1, VT2), and exercise performance (W) values are independent of each other

6. METHODS

6.1 Subjects

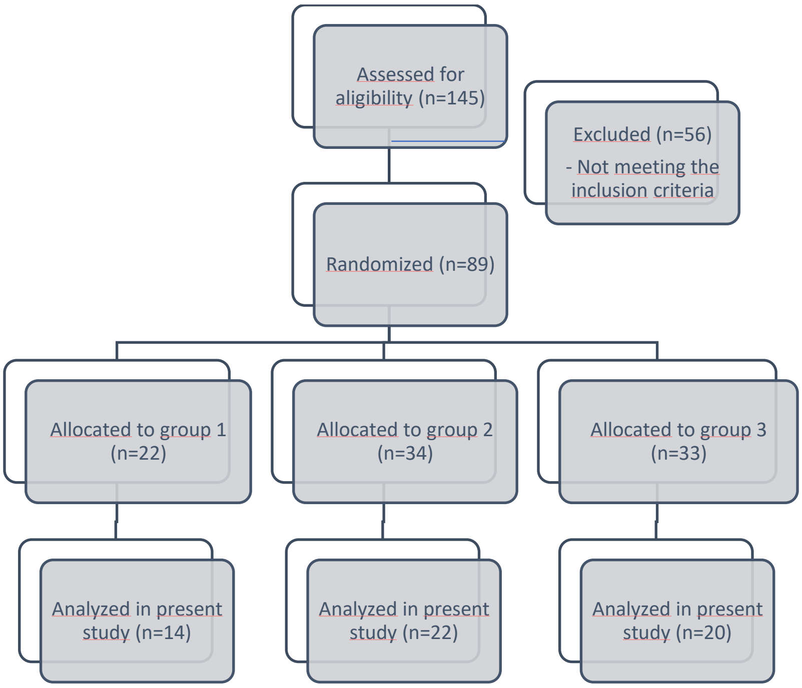
Voluntary subjects (age 18-40 years) in this study included overweight / obese men and women, with referral from a physician to consult lifestyle clinic due to physical inactivity and overweight / obesity, and suitable for exercise testing and training, were recruited to the study through different health care institutions.

Exclusion criteria´s were age <18 and >40 years, neurological or psychiatric disorder, cortisone tablet per so treatment or other medication influencing glucose homeostasis (except insulin), multiple pregnancy, physical disability, substance abuse, significant co-operation difficulties, smoker, regular β-blocker or SSRI medication, severe anemia, prisoner.

Totally 145 person was contacted, and the initial sample consists of 89 subjects, 34 male (38%) and 55 female (62%). Subjects gave their written informed consent prior to participating in the study. The study conformed to the Declaration of Helsinki and was approved by the Ethics Committee of Hospital District of Helsinki and Uusimaa, Helsinki, Finland.

All subjects were native/fluent in Finnish because some of the mobile apps were available only in Finnish.

FIGURE 13. Participant’s process.



6.2 Study design

The subjects interested into participating in the intervention were randomized into three groups. Group 1 represents current general exercise and nutrition guidelines, while Group 2 represents personalized intervention approach and Group 3 highly personalized intervention approach. The depth of exercise instructions separate Group 2 and Group 3 from each other. This intervention represents a dose-response setting.

Group	Approach	Focus 1	Focus 2
Group 1	General guidelines	The effectiveness of general guidelines in improving anthropometric profile by reducing body weight, BMI, body fat percentage, and visceral fat.	The effectiveness of general guidelines in improving Peak power, VO_{2peak}, VT1, VT2.
Group 2	Individualized	The effectiveness of personalized intervention in improving anthropometric profile by reducing body weight, BMI, body fat percentage, and visceral fat.	The effectiveness of personalized intervention in improving Peak power, $VO2_{peak}$, VT1, VT2.
Group 3	Highly individualized	The effectiveness of highly personalized intervention in improving anthropometric profile by reducing body weight, BMI, body fat percentage, and visceral fat.	The effectiveness of highly personalized intervention in improving Peak power, VO_{2peak}, VT1, VT2

6.3 Measurements

The participants (N = 89) were randomized into three groups. The PI of the study generated the random allocation sequence. Research nurses who oversaw scheduling laboratory visit times randomly allocated participants after the subject's announcement to voluntary participate in the study. A blinded draw of a paper containing a number 1, 2, or 3 was performed to randomly allocate participant to Group 1, 2, or 3. Subjects visited the laboratory three (Group 1 and 3) or four (Group 2) times.

During the first visit, participants height, weight, and body composition by bioimpedance were assessed, and self-report questionnaires on physical activity, psychology, music use, as well as work productivity and activity impairment fulfilled.

During the second visit, a physician examined each subject to ensure his/ her suitability for exercise testing and training. Thereafter, each subject performed a step-incremental cardiopulmonary exercise test on a cycle ergometer (Monark Ergometric 839 E, Monark Exercise AB, Vansbro, Sweden) until voluntary fatigue with recordings of pulmonary ventilation (Triple V, Jaeger Mijnhardt, Bunnik, The Netherlands), alveolar gas exchange (Oxycon Pro, Hoechberg, Germany), ECG (PowerLab, ADInstruments, Oxford, UK) and ratio of perceived exertion (RPE).

All groups did very advanced measurements routinely used in laboratory. Clinical cardiopulmonary exercise stress test (CPET) with a step incremental protocol on a cycle ergometer until volitional fatigue to monitor exercise responses and the determinants of cardiorespiratory fitness. Extensive and advanced technologies was used, including breath-by-breath ventilation and alveolar gas exchange (e.g., VO_{2peak}); automatic arterial blood pressure (BP) from the brachial artery. The CPET will provide comparable physiological data of the groups and individuals to other groups and individuals.

On the third visit, fast blood tests were taken, and the person got feedback on the measurements and instructions for the 3-month intervention in analogy of his/her group guidelines. On the fourth visit group 2 performed incremental 12 minutes submaximal cycle ergometer test, which was used to individualize their interventions in terms of physical exercise. This was the main difference between group 2 and group 3 interventions.

To support participants' own planning and follow-up of their physical activity, exercise training and other health behaviors, subjects within Groups 2 and 3 were instructed to use smart phone applications. Sports Tracker (Amer Sports Digital Services Oy, Vantaa, Finland) with a heart rate belt (Suunto Oy., Vantaa, Finland) was used to guide and record exercise training, Argus (Azumio Inc, Redwood City, CA, USA) or equivalent to count daily steps, and Weight Diary (CurlyBrace Apps Ltd, UK) or equivalent to measure weight. The study web page provided further instructions and support for training. A 3-month Spotify gift card along with examples of playlists was provided to subjects assigned to Groups 2 and 3 to motivate their exercise training and support relaxation.

To monitor, guide and enhance the persistence of healthy lifestyle, major check points for mobile and cloud data were occurred at 0,1-, and 3-month marks. The subject´s estimate on success of the intervention including usability of mobile applications (questionnaire).

6.4 Interventions

Group1 subjects received general guidelines based on UKK Institutions recommendations for healthy diet and physical activity, but they did not receive individually tailored programs, yet measurements were repeated after 3 months.

Group 2 subjects received multiprofessional team and wellness technology support. In collaboration with the subject, the members of the multiprofessional team provided their expertise in individualizing the intervention in terms of physical exercise, nutrition, and use of music in boosting the exercise and helping in relaxation. A multimedia-type “User’s Guide,” including possibilities to peer-support, were developed for Group 2 and Group 3 to steer participants and reinforce their commitment to the intervention.

Group 2 Exercise intervention included: Clinical status, personal goals, preferences and estimated VO_{2peak} were used to individualize exercise intervention.

Group 3 received Clinical status, personal goals, preferences, measured exercise capacity, VO_{2peak} and ventilatory thresholds were used to individualize intervention by determining optimal intensity zones and volumes for individual exercise training. Semi-supervised strength training was provided at the Unisport for those willing to participate.

In collaboration with the Group 3 subject, the members of the multiprofessional team provided their expertise in individualizing the intervention in terms of physical exercise, nutrition, and use of music in boosting the exercise and helping in relaxation. Mobile and cloud technologies were used to fine tune the intervention based on subjective feedback and emotions, exercise and recovery data, and nutrition data accumulating during the intervention period. Exercise training was finetuned in comparison to Group 2 by utilizing individual heart rate and intensity training zones obtained by ventilatory thresholds in CPET. Timing of measurements and follow-ups are like Group 2.

7. STATISTICAL ANALYSIS

IBM SPSS V26 (IBM, New York, USA) was used for all statistical analyses. Descriptive statistics were performed to summarize baseline characteristics of the participants. This data is presented with means and standard deviations (SD and the range).

The relative changes in values with all the participants were analyzed according to the intervention time (3 month) with an independent samples *t*-test. For group differences between groups to analyze effect of interventions mixed linear model analyses with group and time interaction were performed (Two way repeated Anova one-between and one-within). Bonferroni correction was used to determine the level of significance when a significant main effect was found.

Comparable changes between groups were determined by dividing absolute delta by the pretrial value x 100. Individual improvements in all variables were also determined between groups using absolute delta values. Pearson´s correlations were used to determine the relationships between anthropometrical and cardiovascular fitness values.

The outcome variables were assessed for normality with the Shapiro-Wilk test to assure all variables met the assumptions of the statistical tests used. For all analyses, the statistical significance was set at $p<0.05$ (two-tailed), meaning that any value below this number was considered significant.

Data are reported as means, SD with ranges reported as minimum-maximum for participants or groups, and where significant differences of $p<0.05$ was considered different between participants or groups with-in and with-out time.

8. RESULTS

All results are presented in same order: all participants, between groups, relative group changes and individual changes.

8.1 Baseline characteristics

The baseline characteristics of all the subjects are presented in table 5.

TABLE 5. Baseline data of the subjects

MODE	Age	Height	Weight	BMI
1	35,2 ± 5,2	171,3 ± 6,6	96,1 ± 11,8	32,8 ± 3,7
2	34,1 ± 5	170 ± 9,8	93 ± 14,7	32,1 ± 4
3	31,1 ± 6	173,3 ± 9,9	106,5 ± 21,2	35,4 ± 6,5
Total	33,3±5,6	171,5±9,2	98,7±17,7	33,5±5,2

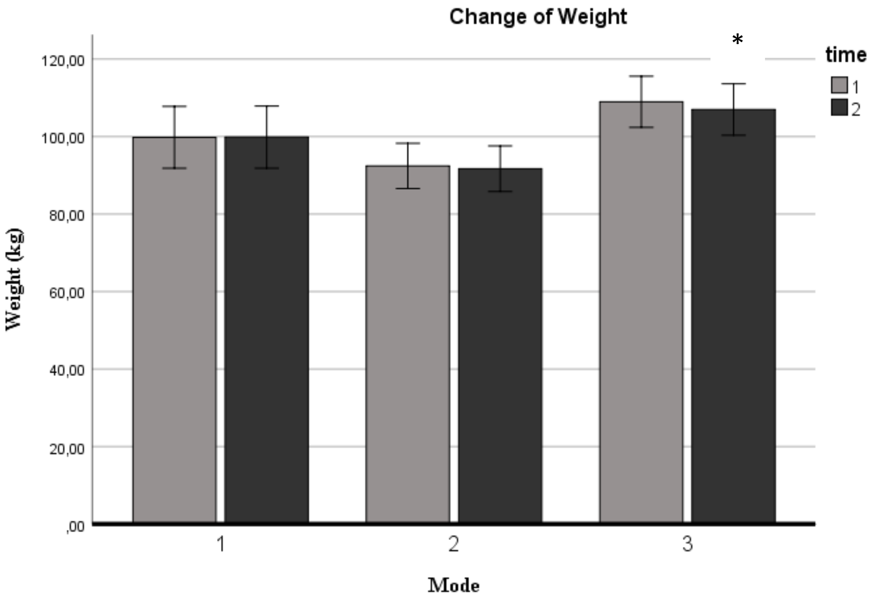
8.2 Anthropometric and body composition changes

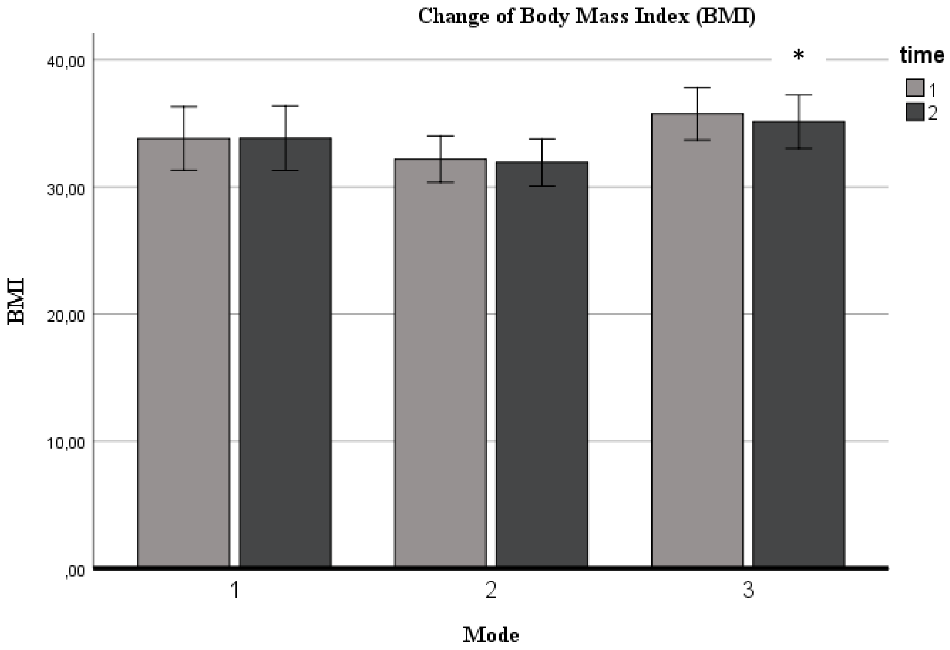
The anthropometric changes of all participants are presented in table 6. Statistically significant changes were observed in weight (-1,0 ± 3,4kg, p<0.05), BMI (-0,3 ± 1,1, p<0.05) and at bodyfat -0.82±2,3%, p<0.01), but not in fat free mass (table6).

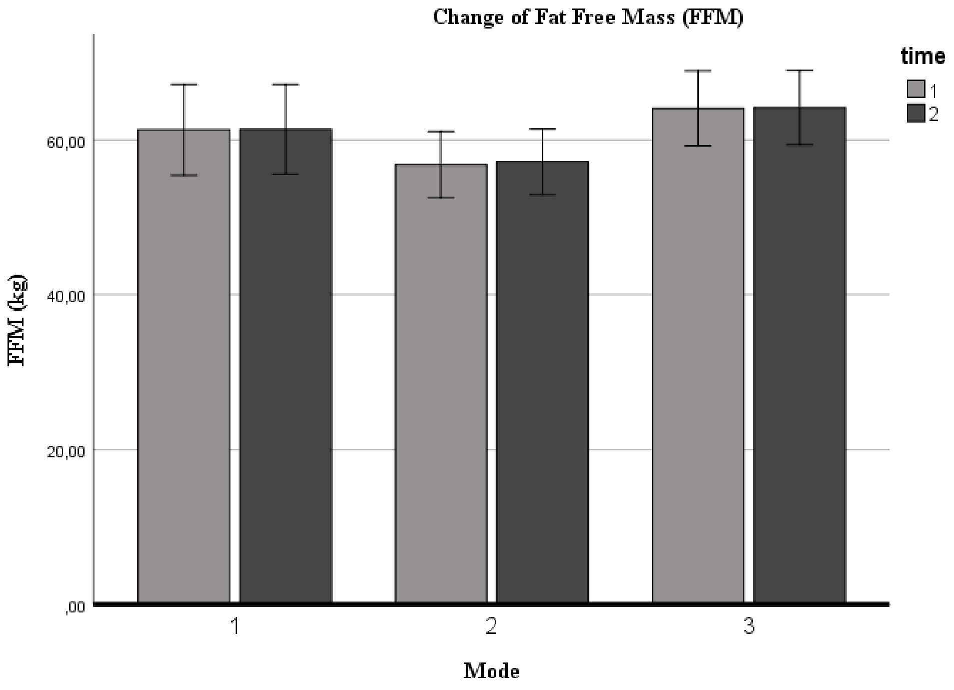
*TABLE 6. Anthropometric changes of all participants (0 vs. 3 month) *Significant difference between measurements (P< 0.05).*

	0 month	3 month	Change	Sig.
Weight (kg)	99,7±16,9	98,8±16,7	-1,0± 3,4	.025*
BMI	33,8±5,0	33,5±5,0	-0.3± 1,1	.028*
BF (%)	39,3±8,2	38,4±8,3	-0.82± 2,3	.005**
FFM (kg)	60,3±11,6	60,5±11,5	0.2± 2,1	.446

The anthropometric changes between groups are presented in Figure14. The group3, which had highly individual training intervention had statically significant changes in weight (-2 kg, p<0.01), BMI (-0,7, p<0.01) and bodyfat% (-0,7, p<0.01), but not in fat free mass. Group 1 and 2 had no statically significant changes in anthropometry.


Change of Weight
*
time
1
2
Weight (kg)
120,00
100,00
80,00
60,00
40,00
20,00
,00
1
2
3
Mode


Change of Body Mass Index (BMI)
*
time
1
2
BMI
40,00
30,00
20,00
10,00
,00
1
2
3
Mode



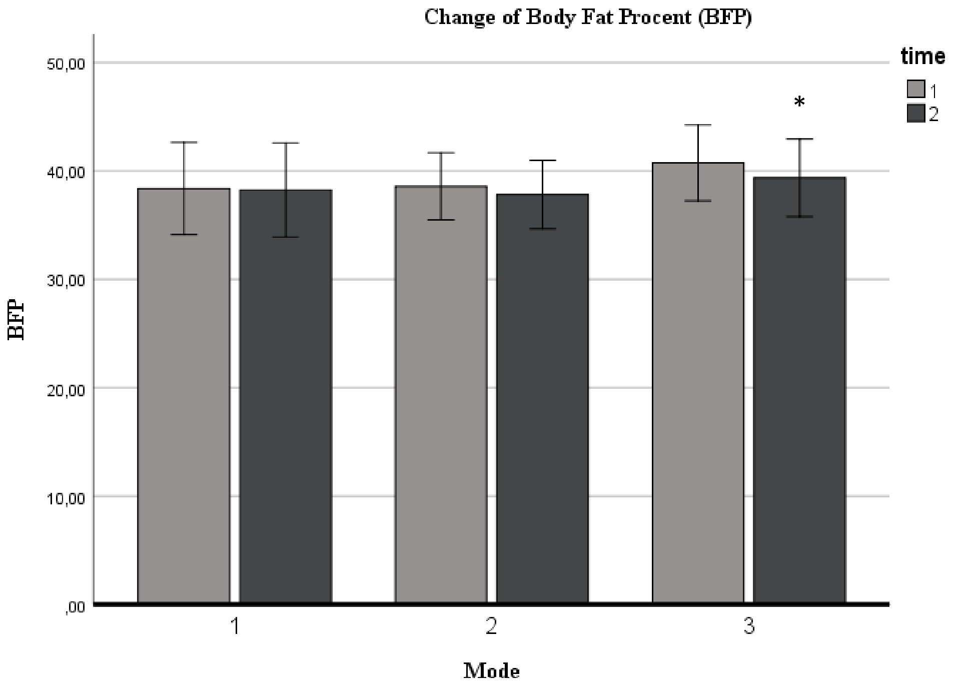


*FIGURE 14. Changes from 0 to 3 month in anthropometry at intervention groups (1,2 and 3). *Significant differences at group3 (P<0.05)*

The relative changes expressed as percentage from pretrial values (%) in anthropometric are presented in figure15. In addition to the data positive changes were observed at all the groups in weight, BMI and bodyfat, but not at fat free mass. The biggest relative changes were observed in group 3 (weight 1,8%, BMI 1,8%, BF 3,7%)

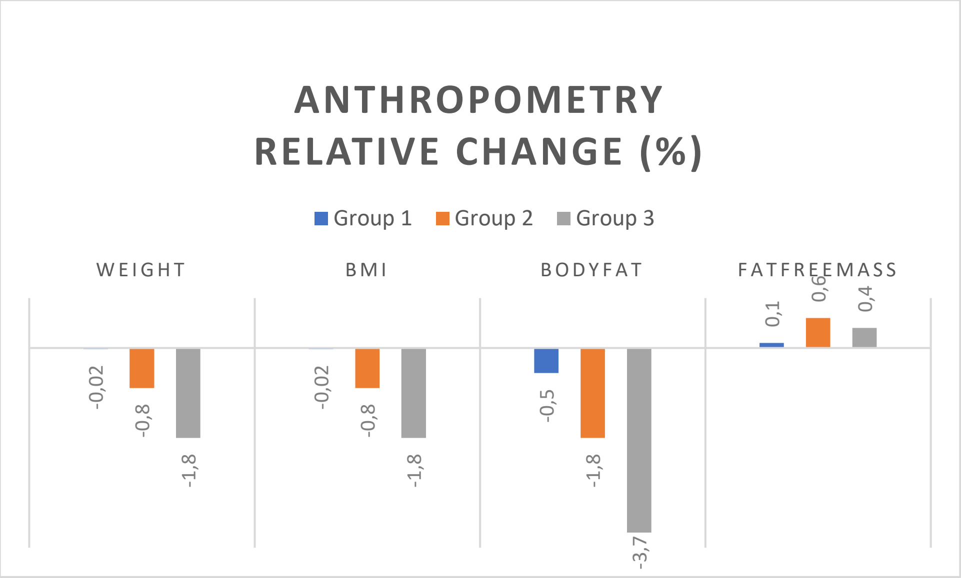


FIGURE 15. Relative changes (%) from 0 to 3 month in anthropometry in the intervention groups (1,2 and 3).

The individual changes (+/- from 0 month to 3 month) in anthropometry are presented in figure16. In group 3 62% of participants could decrease their weight, 62% decreased BMI, 67% fat free mass and 52% could increase their fat free mass. In group 2 changes at same order were 61%, 50%, 67% and 52%, and in group 1 46%, 46%,42% and 50%.

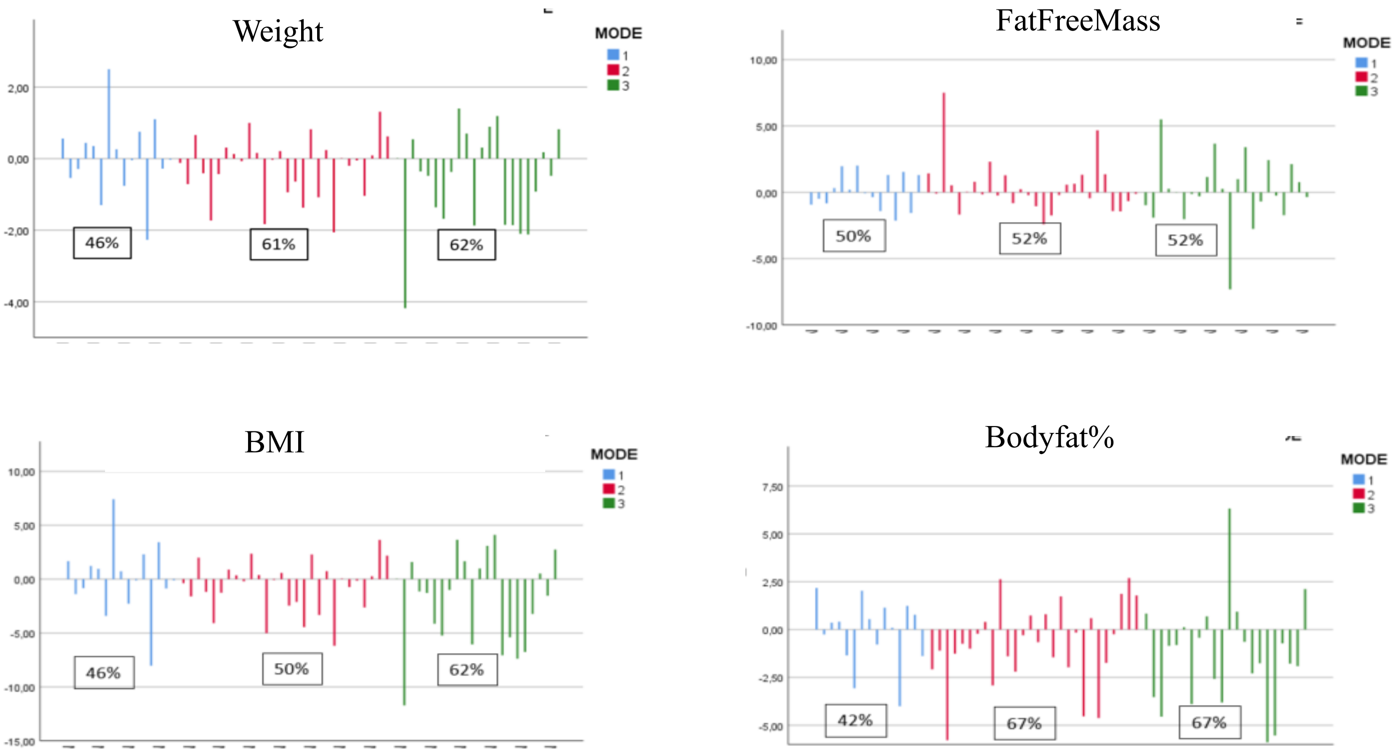


FIGURE 16. Individual changes (+/-) from 0 to 3 month in anthropometry in the intervention groups (1,2 and 3).

8.3 Cardiorespiratory changes

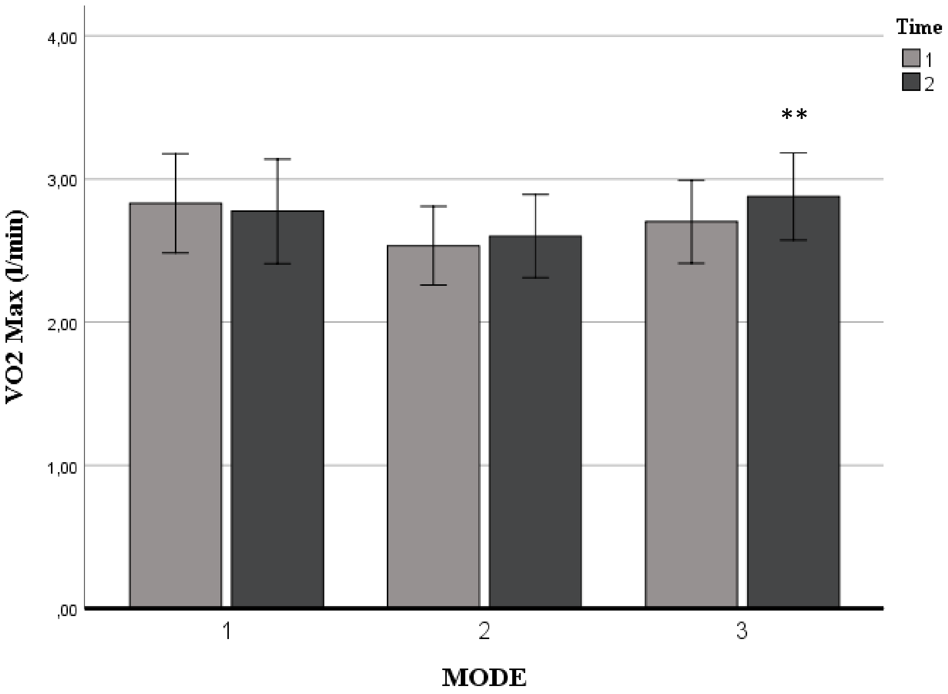
8.3.1 Cardiorespiratory changes at VO_{2peak} and ventilatory thresholds

Results from all participants in VO_2 are presented in table 7, showing significant improvements in VO_2 at peak level in ml/kg/min, $p<0.01$), at ventilatory threshold1 level in l/min ($p<0.01$), in ml/kg/min, ($p<0.01$) and in ml/ffm/min ($p<0.01$). and at ventilatory threshold 2 level in ml/kg/min ($p<0.01$

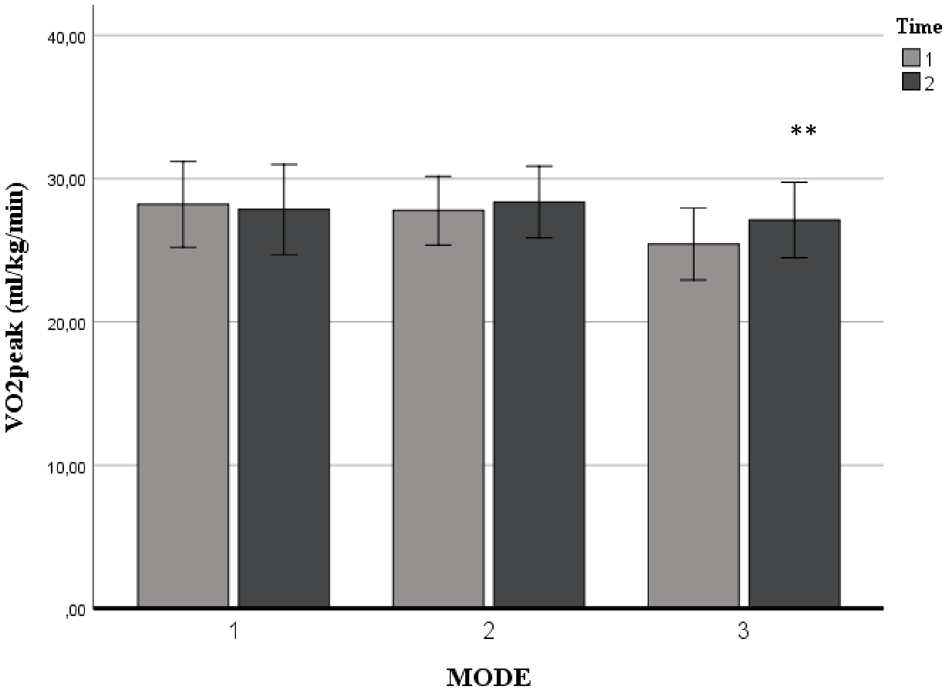
*TABLE 7. VO_2 changes of all participants (0 vs. 3 month) *Significant difference between measurements ($P< 0.05$).*

	0 month	**3 month**	**Change**	**Sig**
VO_{2peak} (l/ min)	2,67±0,64	2,74±0,68	0,08±0,28	.046
VO_{2peak} (ml/kg/min)	27,1±5,6	28,1±6,1	1,1±3,2	.014*
VO_{2peak} (ml/ffm/min)	44,4±6,1	45,3±6,8	1,0±5,1	.159
VO_2 VT1 /l/min)	1,43±0,35	1,51±0,37	0,08±0,24	.018*
VO_2 VT1 /ml/kg/min)	14,6±3,4	15,5±3,5	0,9±2,6	.010*
VO_2 VT1 (ml/ffm/min)	23,9±4,2	25,1±4,4	1,1±4,0	.043*
VO_2 VT2 (l/min)	2,19±0,51	2,26±0,51	0,07±0,27	.053
VO_2 VT2 (ml/kg/min)	22,2±4,6	23,3±4,6	1,0±3,1	.025*
VO_2 VT2 (ml/ffm/min)	36,5±5,1	37,5±5,2	1,0±4,9	.134

The VO_2 results between groups are presented in figures 17, 18, and 19. The group3, which had highly individual training intervention had statically significant changes at peak level l/min ($p<0.01$) ml/kg/min ($p<0.01$) ml/ffm/min ($p<0.01$), at VT1 level l/min ($p<0.01$) ml/kg/min ($p<0.01$) ml/ffm/min ($p<0.01$) and at VT2 level l/min ($p<0.01$) ml/kg/min ($p<0.01$) ml/ffm/min ($p<0.01$). Group 1 and 2 had no statically significant changes in VO_2 levels.



VO2 Max (l/min)
4,00
3,00
2,00
1,00
,00
1
2
3
MODE
Time
1
2
**



VO2peak (ml/kg/min)
40,00
30,00
20,00
10,00
,00
1
2
3
MODE
Time
1
2
**

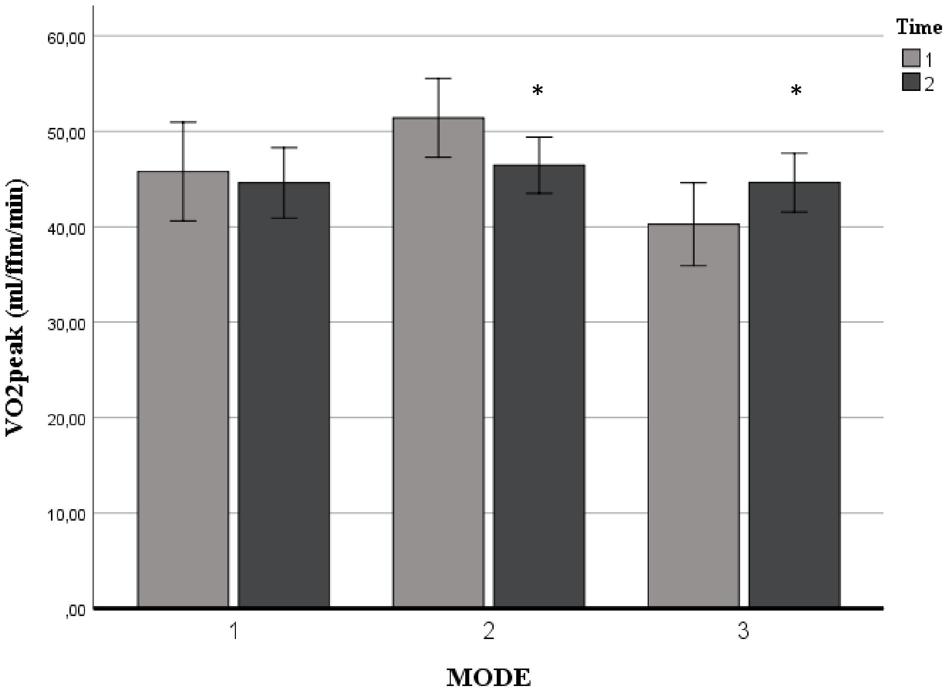
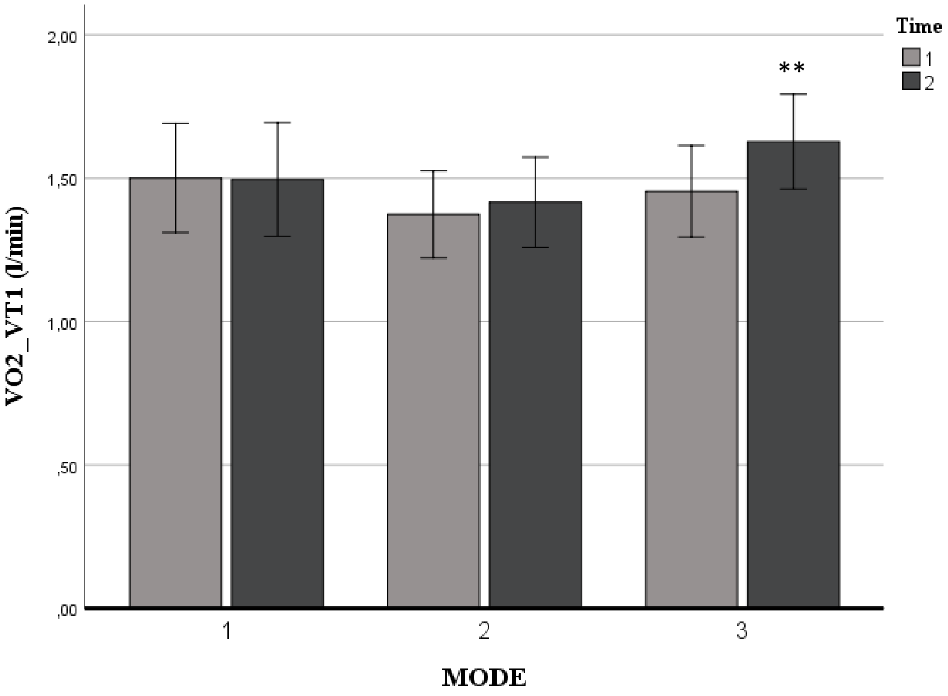
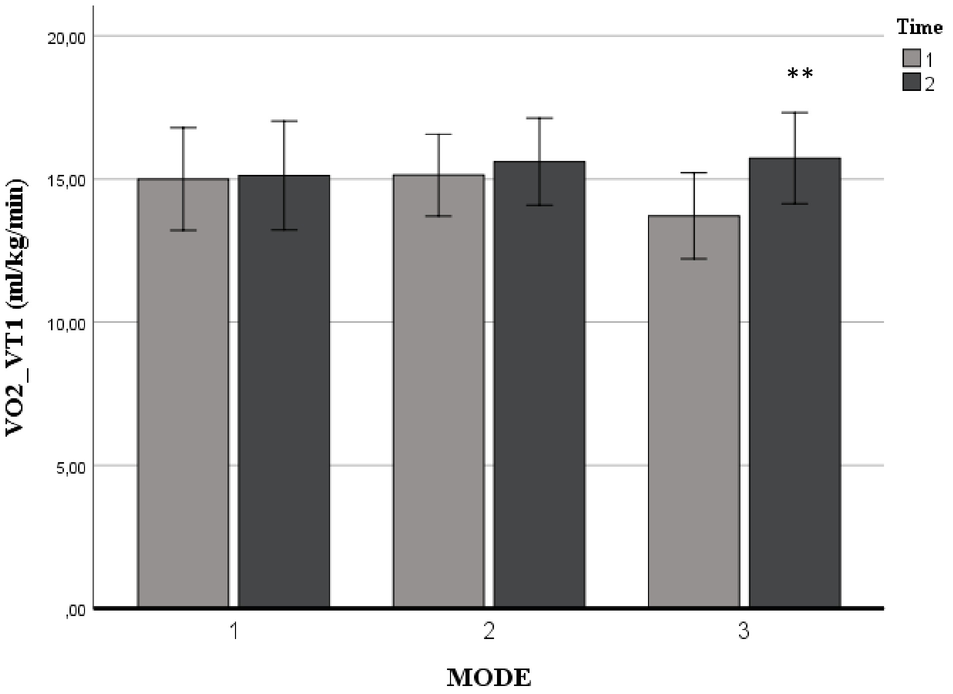


FIGURE 17. Changes from 0 to 3 month in $VO_{2\,peak}$ *level in the intervention groups (1,2 and 3). *Significant differences in all values in group 3 (P<0.05) and negatively significant change in group 2 at ml/ffm/min.*





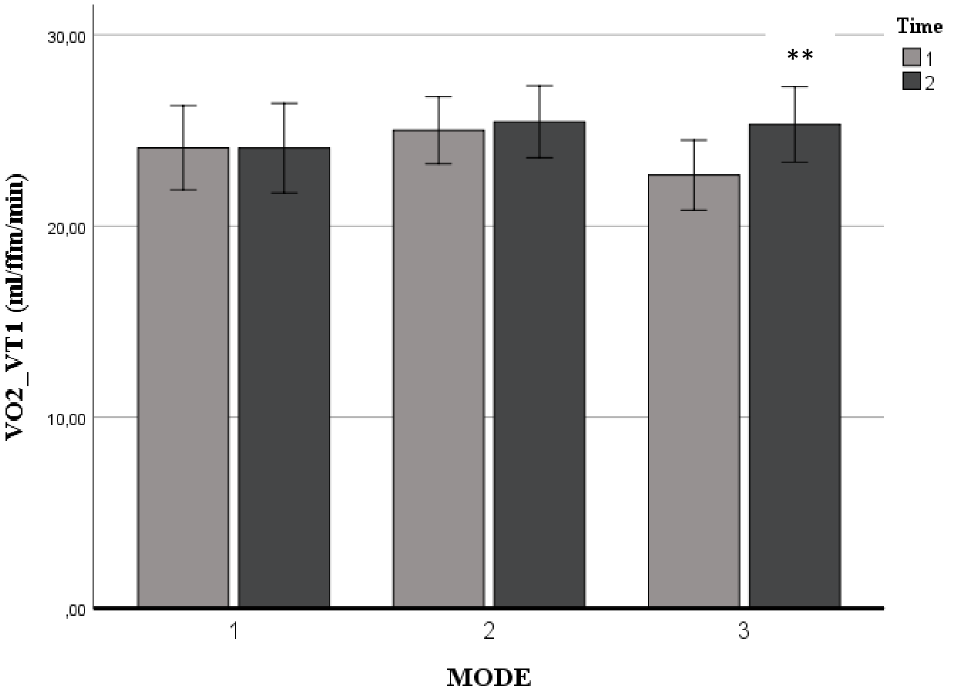
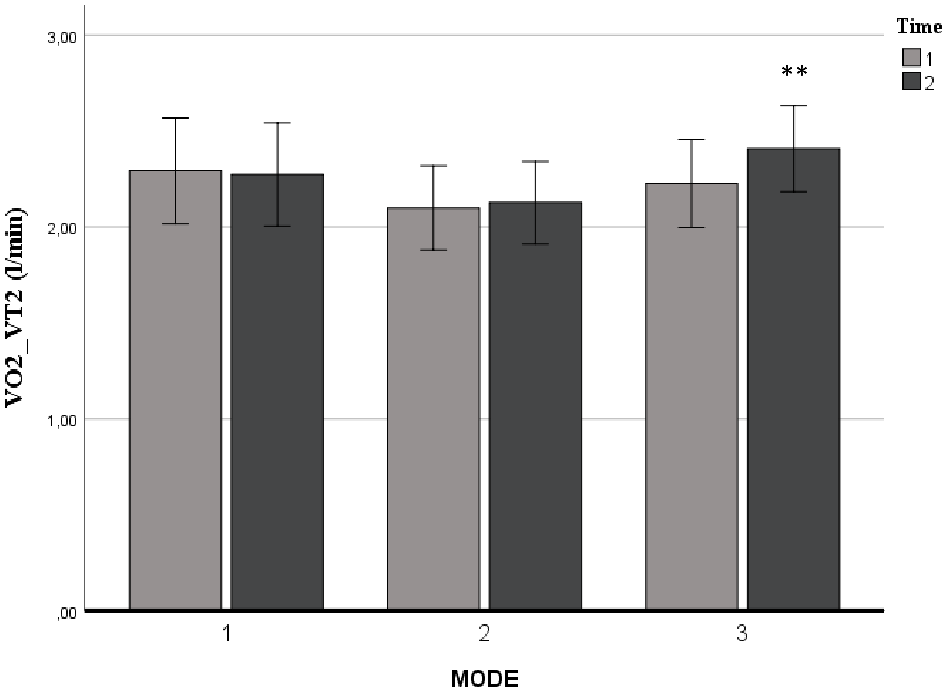
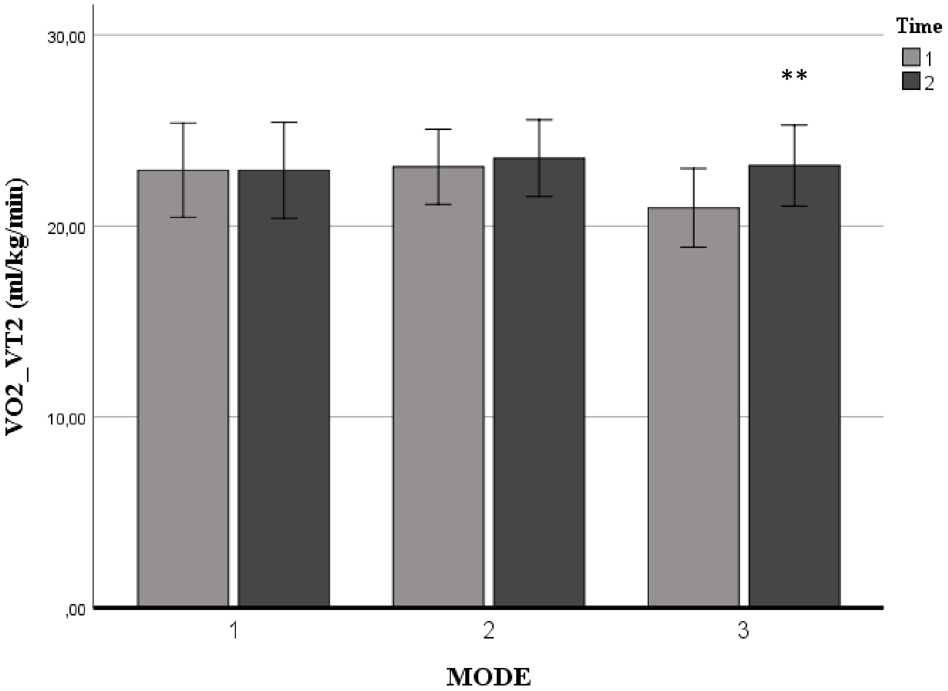


FIGURE 18. Changes from 0 to 3 month in $VO_{2\ VT1}$ *level in the intervention groups (1,2 and 3). *Significant differences in all values in group 3 (P<0.05)*


Time
1
2
**
3,00
2,00
1,00
,00
VO2_VT2 (l/min)
1
2
3
MODE


Time
1
2
**
30,00
20,00
10,00
,00
VO2_VT2 (ml/kg/min)
1
2
3
MODE

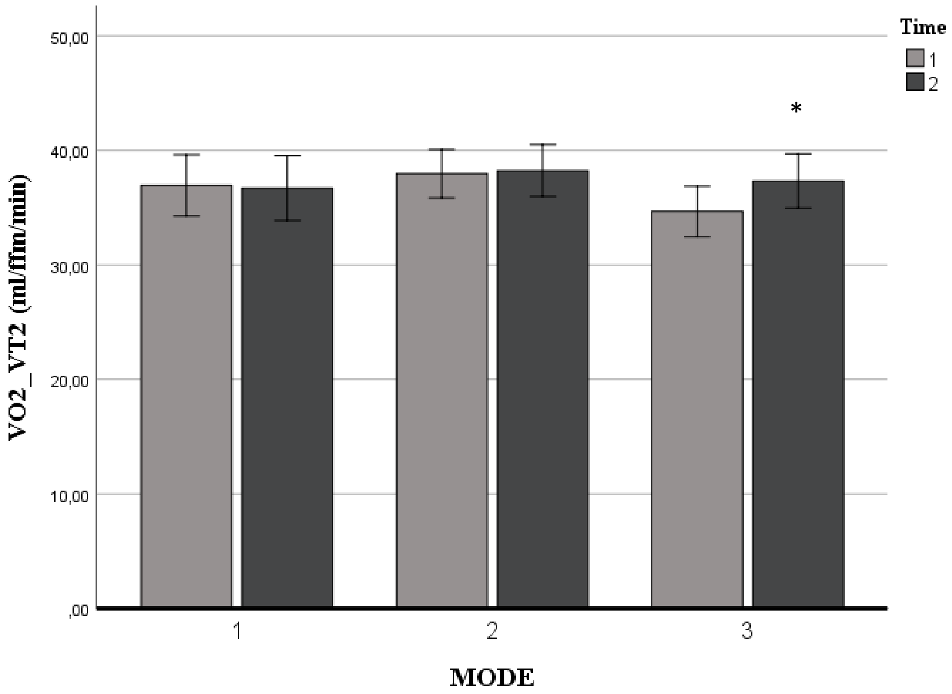


*FIGURE 19. Changes from 0 to 3 month in $VO_{2\ VT2}$ level in the intervention groups (1,2 and 3). *Significant differences in all values in group 3 ($P<0.05$)*

The relative changes expressed as percentage from pretrial values (%) in VO_2 values are presented in figure20. In addition to the data positive changes were observed at the groups 2 and 3 in all values. The biggest relative changes were observed in group 3 between 6,4% to 15,5%.

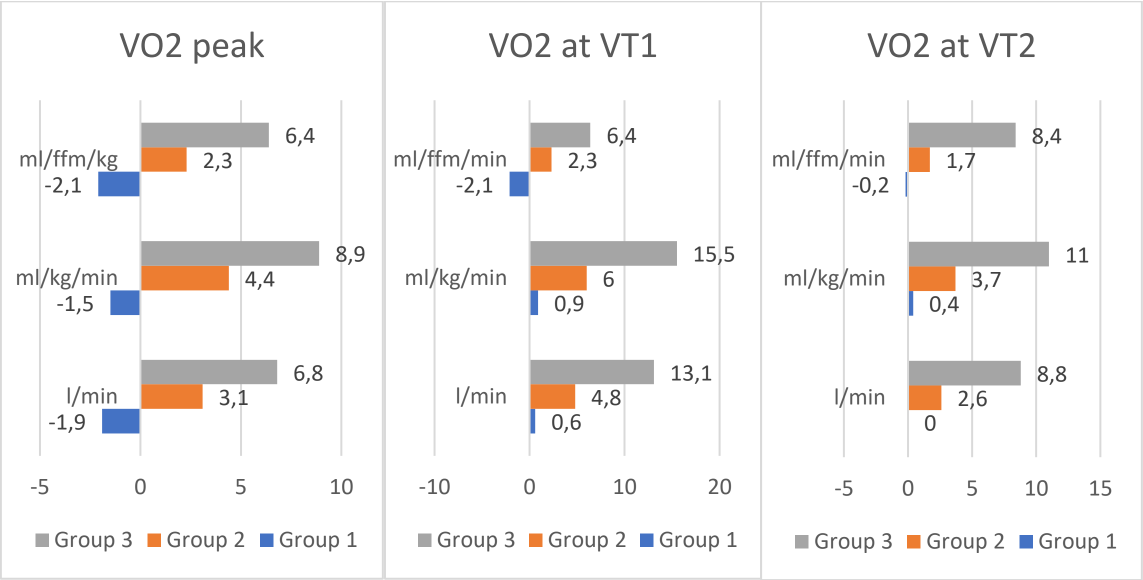


FIGURE 20. Relative changes (%) from 0 to 3 month in VO_2 at peak, VT1 and VT2 level in the intervention groups (1,2 and 3).

The individual changes (+/- from 0 month to 3 month) in VO_2 values (l/min, ml/kg/min, ml/ffm/min) are presented in figures 21, 22, and 23. In group 3 in VO_{2peak} level 79% of participants could improve their l/min value, and 80% at VT1 and VT2 levels. In group 2 improvements at same levels were 52%, 59%, and 59%, and in group 1 54%, 38%, and 46%.

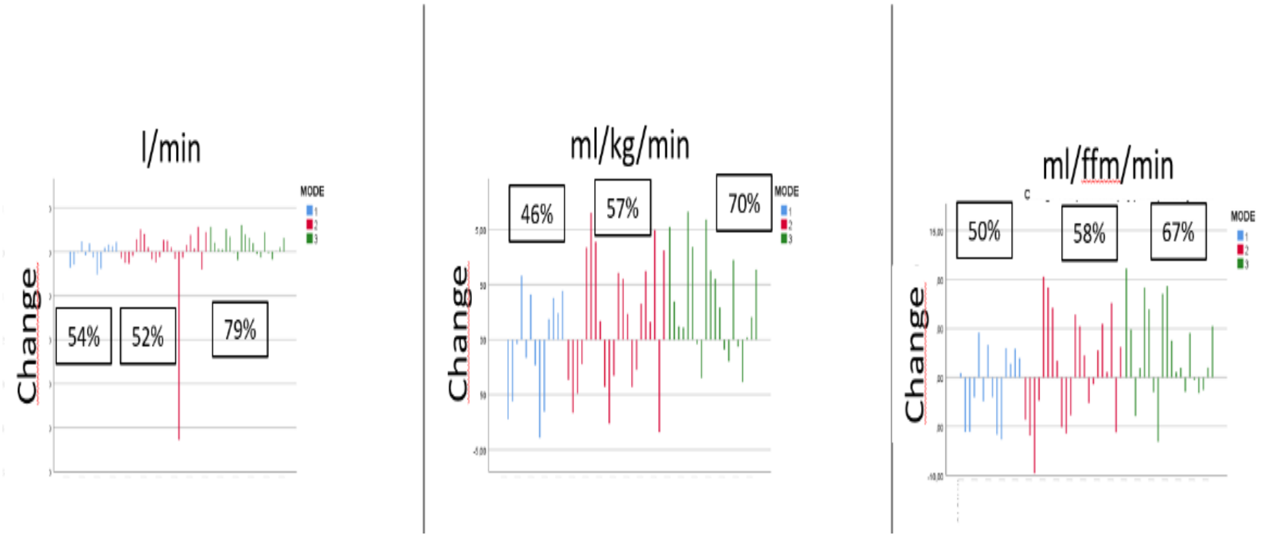


FIGURE 21. Individual changes (+/-) from 0 to 3 month in VO_{2peak} in the intervention groups (1,2 and 3).

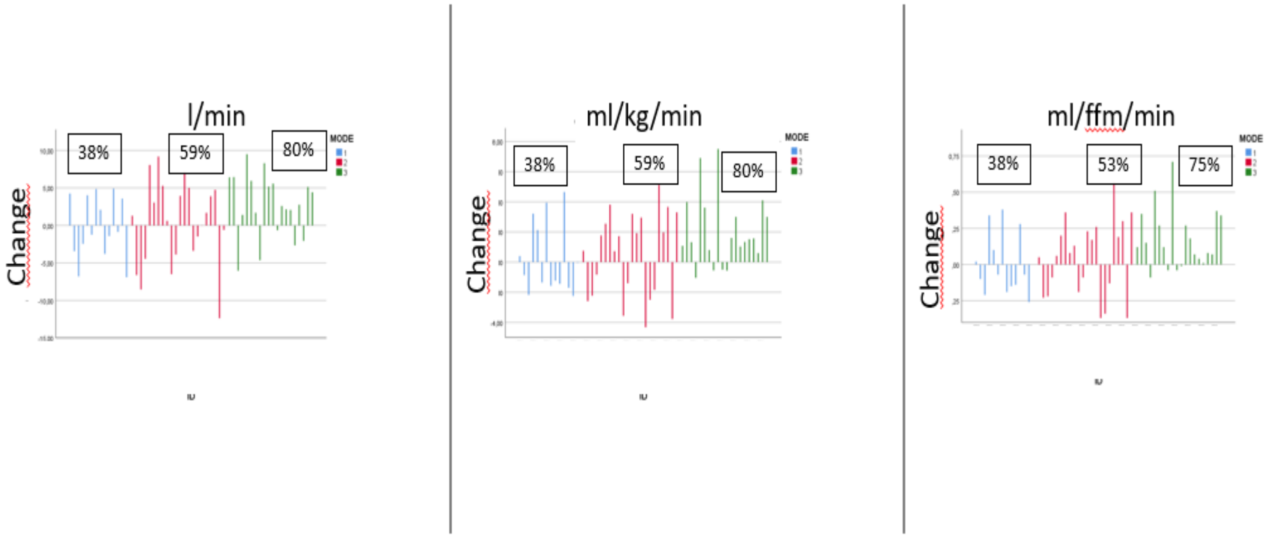


FIGURE 22. Individual changes (+/-) from 0 to 3 month in VO_{2VT1} in the intervention groups (1,2 and 3).

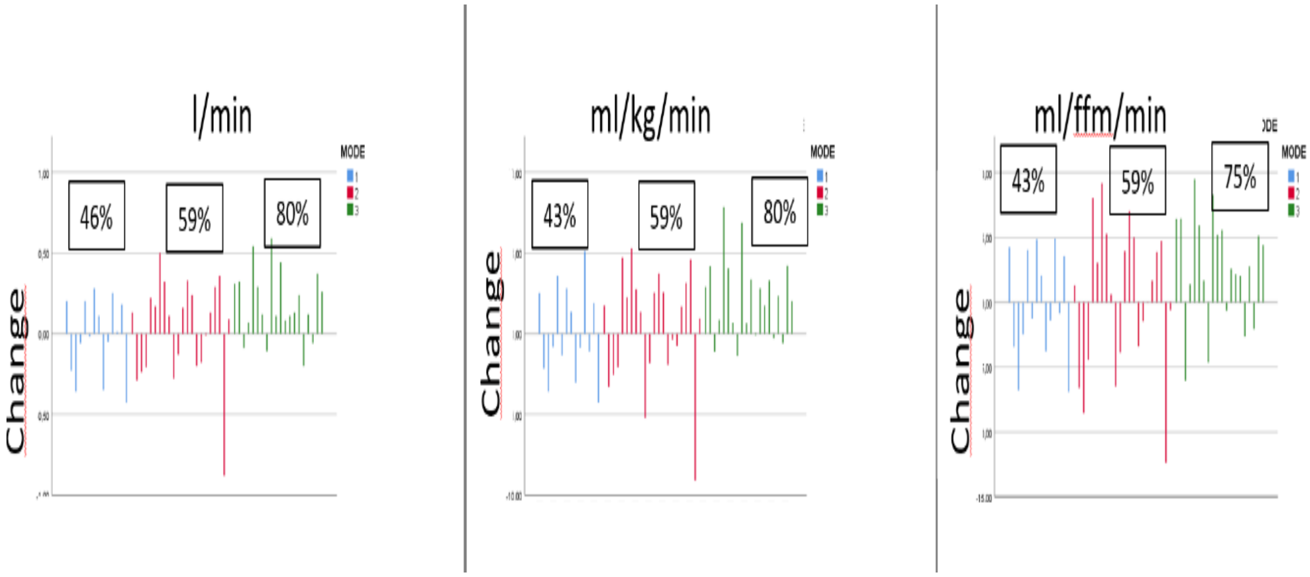


FIGURE 23. Individual changes (+/-) from 0 to 3 month in VO_{2VT2} *in the intervention groups (1,2 and 3).*

8.3.2 Cardiorespiratory changes at a moderate workload

At a moderate workload (60W female, 80W male), which was approximately 40% of the peak value, occurred statistically significant changes in heart rate (HR) in group 2 ($p<0.01$) and 3 ($p<0.01$) and in all the participants ($p<0.01$). In addition, in diastolic blood pressure (DBP) occurred significant changes in group 2 ($p<0.01$) and all participants ($p<0.01$). Group 3 had significant change in RPE ($p<0.01$). (table8)

TABLE 8. Cardiorespiratory changes (heart rate, systolic blood pressure, diastolic blood pressure, main arterial pressure, RPE) at a moderate workload

	0 month				3 month				Change				Sig			
Group	1	2	3	All	1	2	3	All	1	2	3	All	1	2	3	All
HR	121	123	124	123	121	119	119	119	0	-4	-5	-4	.772	.025*	.005**	004**
SBP	164	152	157	158	159	146	156	154	-3	-6	-1	-4	.264	.099	.709	.074
DBP	88	84	86	86	83	79	84	82	-5	-5	-2	-4	.086	.013**	.268	.003**
MAP	114	109	111	111	112	107	111	109	-2	-2	0	-2	.285	.258	.906	.221
RPE	11	11	12	11	11	11	11	11	0	0	-1	0	.890	.509	.032*	.269

8.3.3 Heart rate

Changes in heart rate at rest, maximal, VT1 and VT2 levels are presented in table 9. No significant changes occurred. between 0 to 3-month intervention.

TABLE 9. Changes in heart rate at rest, maximal, VT1 and VT2 levels.

	0 month			3 month			Change			Sig		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
Max	181	178	178	182	179	179	1	1	1	.424	.609	.737
VT1	127	126	127	130	127	128	3	1	1	.389	.836	.583
VT2	161	159	159	163	160	159	2	1	0	.533	.936	.926
Rest	54	54	51	58	57	54	4	3	3	.277	.201	.314

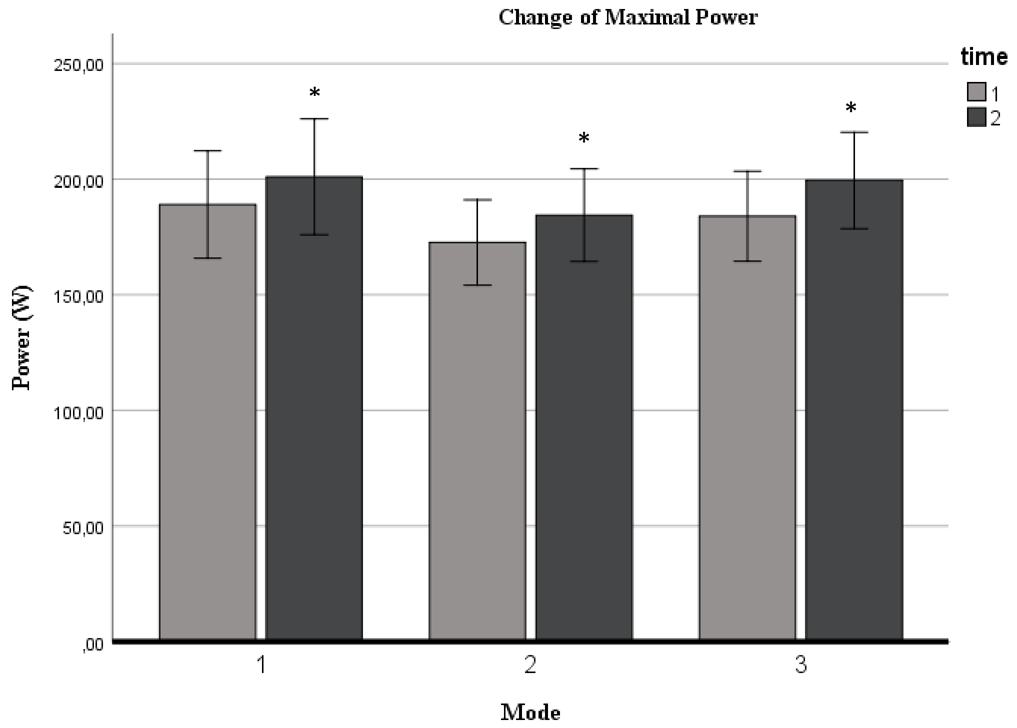
8.4 Exercise Performance

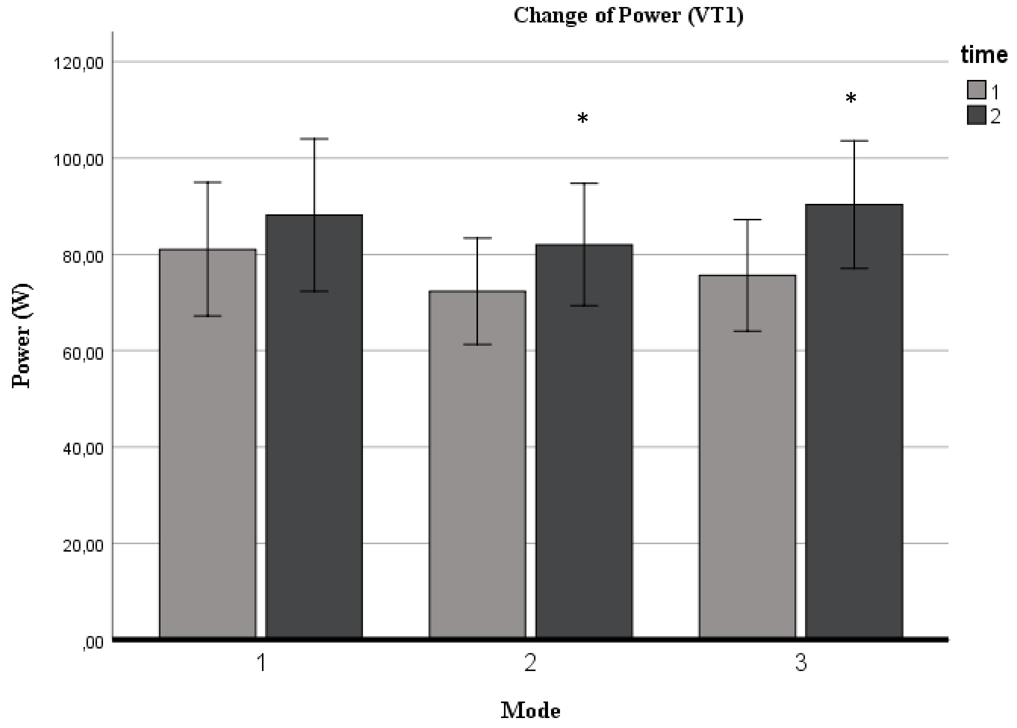
All participants (n=56) had statistically significant changes at maximal power output (p<0.01), and power output at VT1 (p<0.01) and at VT2 (p<0.01). (table10)

TABLE 10. Changes in exercise performance (W) between 0 to 3 months at peak, VT1 and VT2 levels.

	0 month	3 month	Change	Sig.
Power max (W)	180±43	194±47	13±17	.000*
Power VT1 (W)	75,69±25,59	87±29	12±21	.000*
Power VT2 (W)	139±34	151±35	11±21	.000*

The exercise performance (W) changes between groups are presented in figure24. The group3, had statically significant changes at peak level (p<0.01), at VT1 (p<0.01) and at VT2 level (p<0.01). Group 2 had also statically significant changes at peak (p<0.01), VT1 (p<0.05) and VT2 (p<0.01) levels. Group 1 had statistically significant improvement at peak level (p<0.01).


Change of Maximal Power
time
1
2
Power (W)
250,00
200,00
150,00
100,00
50,00
,00
*
*
*
1
2
3
Mode


Change of Power (VT1)
time
1
2
Power (W)
120,00
100,00
80,00
60,00
40,00
20,00
,00
*
*
1
2
3
Mode

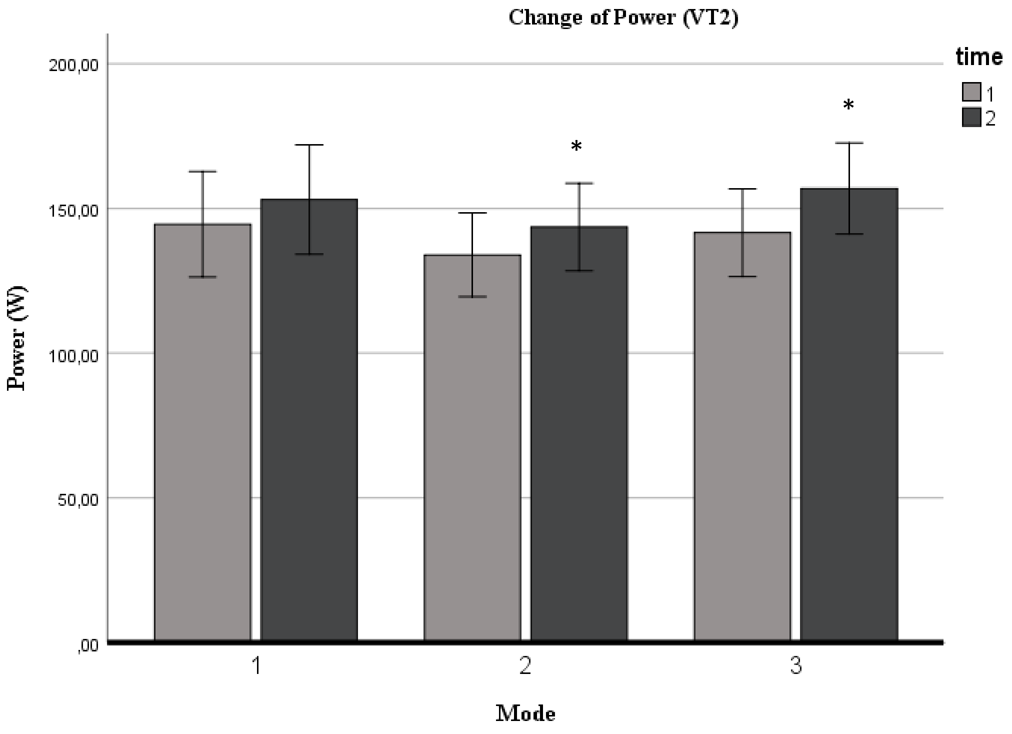


*FIGURE 24. Changes from 0 to 3 month in exercise performance level in the intervention groups (1,2 and 3). *Significant differences in all values in group 2 and 3 (P<0.05) and in peak level in group 1.*

The relative changes expressed as percentage from pretrial values (%) in exercise performance values are presented in figure 25. In addition to the data positive changes were observed in all groups in all values. The biggest relative changes were observed at VT1 level, 12,4% in group 1, 20,9% in group 2, and 21,6% in group 3.

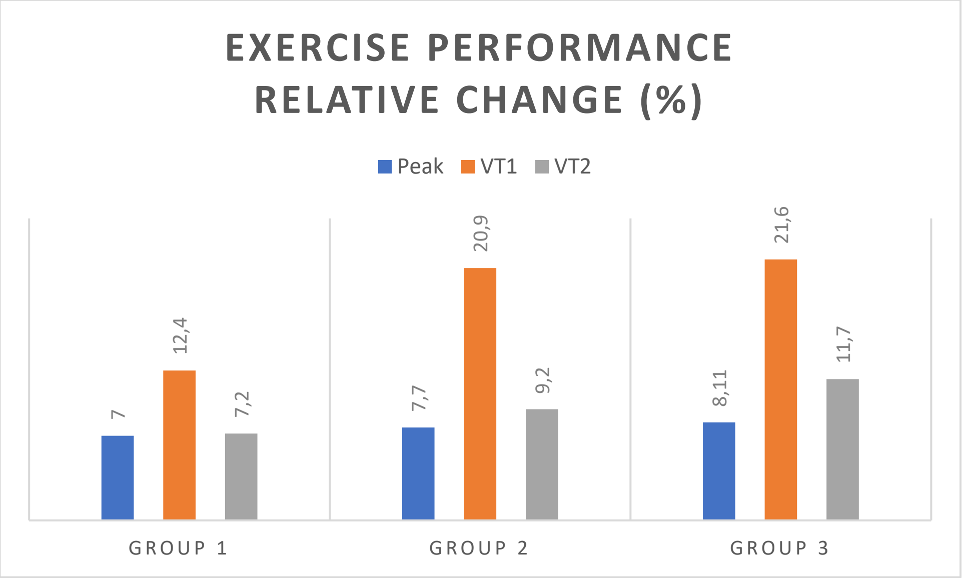


FIGURE 25. Relative changes (%) from 0 to 3 month in exercise performance in the intervention groups (1,2 and 3).

The individual changes (+/- from 0 month to 3 month) in exercise performance values (W) are presented in figure 26. In group 3 in peak level 90% of participants could improve their value, and 80% at VT1 and 90% at VT2 levels. In group 2 improvements at same levels were 73%, 68%, and 73%, and in group 1 69%, 69%, and 85%.

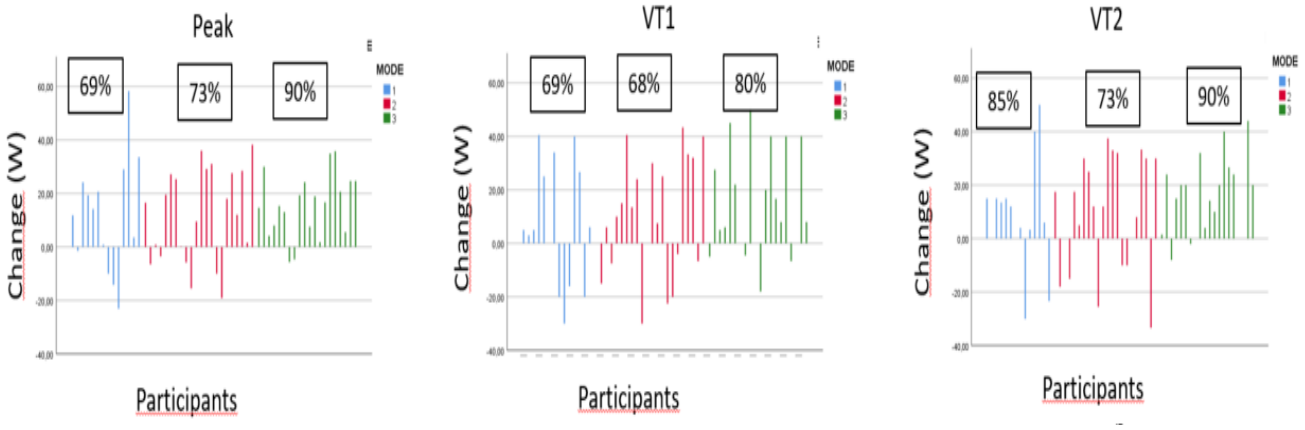


FIGURE 26. Individual changes (+/-) from 0 to 3 month in exercise performance in the intervention groups (1,2 and 3).

8.5 Associations between changes at anthropometric and cardiovascular values

In all participants (n=56) there were positive correlations between changes in oxygen uptake (VO_2) at ventilatory threshold 1 versus weight ($p<0.05$), BMI ($p<0.05$), and body fat percent ($p<0.01$). (table11)

TABLE 11. Associations between changes at anthropometric (weight, body mass index, body fat present, fat free mass) and cardiovascular values (VO_2 at peak, VT1 and VT2 levels and peak power output).

	DVO_{2peak}	DPWpeak	DVO_2_VT1	DVO_2_VT2
Dweight	.620	.135	.039*	.062
DBMI	.571	.120	.043*	.057
DBFP	.236	.202	.021*	.397
DFFM	.350	.960	.594	.376

9. DISCUSSION

The aim of this study was to analyze wether: 1) individually tailored multidisciplinary 3-month exercise intervention was effective in improving anthropometry (weight, BMI, FFM, fat%), cardiorespiratory fitness (VO_{2peak}, VO_{2VT1}, VO_{2VT2}) and exercise performance (W) in overweight and obese subjects; 2) personalized and highly personalized technology-assisted exercise interventions was more effective than general guidelines; 3) a 3-month exercise intervention was effective in improving cardiorespiratory fitness at a given moderate workload (60W female, 80W male) and 4) did expected changes in anthropometry and cardiorespiratory fitness occur simultaneously, or could changes be found independently of each other?

The result of this study supports the hypothesis that positive changes in cardiorespiratory fitness, exercise performance, and anthropometry are more effective with highly personalized training interventions than with general guidelines. Improving and measuring cardiorespiratory fitness is more important than to follow anthropometrical values to get initiation and progress of an effective lifestyle intervention. Improvement reached in exercise performance helps participants to survive at their daily physical activities and continue physical training.

9.1 Anthropometry

Changes in anthropometry with highly personalized, technology-assisted exercise interventions (group 3) were statistically significant as mean weight decreased 1,8%, mean BMI decreased 1,8%, and mean body fat decreased 3,7%. In fat free mass there was no improvement. Group 1 and 2 had no statistically significant changes in anthropometry. There was no weight loss in Group 1.

These results are in line with the previous studies as Chavez-Guevara et al (2020) found in their study that exercise training performed at the maximal fat oxidation intensity decreased weight of 1,88-6,52% and 5,2-28,09% decrease in body fat, however FFM was unchanged. Furthermore, Swift et al (2015) found that overweight and obese adults who follow an exercise program consistent with public health recommendations that does not include a dietary plan, can expect weight loss in the range of zero to 2 kgs.

Stoner et al (2016) concluded in their review that exercise intervention in obese and overweight adolescents' results in meaningful improvements in body composition, particularly body fat. In addition, O`Donoghue et al (2020) pointed out in their meta-analyses that weight loss and reduction of BMI are often main goals in the treatment of obesity, however exercise as an independent intervention induced at best a small reduction in weight loss (-0,05-1,01kg). They also found that BF% is more responsive to exercise than weight. Body fat is the most metabolically harmful tissue type, and therefore it may be a more meaningful measure of health change when evaluating exercise interventions.

This data supports the hypothesis that changes in anthropometry are more effective with personalized interventions than with general guidelines, but the changes are small. That is why following cardiorespiratory fitness values can be more important than anthropometrical values when starting to exercise.

9.2 Cardiorespiratory fitness at VO2peak and ventilatory thresholds

Changes in cardiorespiratory fitness and exercise performance values with highly personalized exercise interventions (Group 3) were more pronounced than with general guidelines (Group 1).

Exercise prescription to participants at Groups 2 and 3 were to mainly exercise with moderate intensity (at and below VT1), make some trainings with severe intensity (at and above VT2), and have regular resistance exercise (once/week). After 12 weeks of training, Group 3 had statistically significant improvements in VO_2 peak (l/min 7%, ml/kg/min 9%, ml/ffm/min 6%), in VO_2 at ventilatory threshold1 (l/min13%, ml/kg/min 16%, ml/ffm/min 6%), and VO_2 at ventilatory threshold2 (l/min 9%, ml/kg/min11%, ml/ffm/min 8%). Groups 1 and 2 had no statistically significant changes at any variable.

Chávez-Guevara et al (2020) found in their meta-analysis a slight VO_{2peak} increase (MD = 2.96 ml/kg/min) after eight to sixteen weeks of intervention at maximal fat oxidation intensity. The observed change represents a mean increase of 10% in participants CRF and is like those reported by Murphy et al. (2007) (2.73 ml/kg/min). In this study VO_{2peak} increased 2,0 ml/kg/min at Group 3, which is in line with results of those previous studies and increases approximately 10% in participants cardiorespiratory fitness.

De Parada et al. (2019) found that VO_{2peak} improvement was independent of training intensity. The largest VO_2 improvement occurred at VT1, as also demonstrated in this study (16%). Mora-Rodriques et al (2014) found a 9% improvement after a 16-week High Intensity Interval Training intervention in VO_{2peak}, which is in line with the results found in this study (9%).

The exercise prescription to participants in Groups 2 and 3 were similar, but only Group 3 had significant improvements in their values. The data supports the findings of Weatherwax et al (2018), who found in their study that after 12 weeks of aerobic exercise training based on individualized exercise interventions using ventilatory threshold measures had a greater effect on the training response compared with an approach using heart rate reserve (HRR).

The data of this study with individual differences inside groups supports the conclusion of Weatherwax et al (2018) that training responsiveness is an individual and not a group phenomenon. Even though the criteria for responsiveness and exercise interventions have focused on group factors. Furthermore, Sarzynski et al (2017) found that there are large individual differences in the gains in VO_{2peak} even when adults are exposed to a standardized and fully monitored exercise training program. They noted that the estimated inherited changes in the trainability of VO_{2peak} reaches 47%.

This study supports the hypothesis that changes in physical fitness are more effective with highly personalized interventions than with general guidelines. The exercise prescription of this study suggesting mainly moderate exercise saw the largest improvements occurred at VT1, and that greater effects on improving cardiovascular fitness can be reached by using ventilatory thresholds than heart rate reserve as a base of training interventions. It is also important to recognize that training responsiveness of cardiovascular fitness is an individual and partly hereditary phenomenon (Ross et al 2016).

9.3 Exercise performance

Exercise performance (W) improved statistically significantly in Groups 2 and 3 in power output at peak and ventilatory threshold (VT1, VT2) levels after 12 weeks training. Group 3 had 8% increase at peak level, 22% at VT1, and 12% at VT2. Group 2 had 8% at peak, 21% at VT1, and 9% at VT2, and Group 1 had a 7% increase at peak level.

There are very few studies which have reported exercise performance results in overweight/obese subjects. Chacaroun et al (2020) found in their study that power outputs improved at peak level and VT2 after 8 weeks of combining exercise training with hypoxic exposure, but not at VT1 or in normoxia.

The present study shows that improvements in exercise performance can occur with all interventions (Groups 1, 2 and 3) at peak power level, but more effectively by personalized interventions (Groups 2 and 3) at VT1 and VT2 levels. This new finding should be studied more because improvements in exercise performance can be crucial for overweight/obese people to continue their training by noticing the effects of training in their daily life which make it possible to increase the load of training.

9.4 Cardiorespiratory changes at a moderate workload

At the present study we show that the effects of a 3-month exercise intervention were not limited to hard and/or severe exercise intensity but improvements can also be seen at a given moderate exercise intensity. Group 3 had a significant decline in HR (4%) and RPE (9%), but not in blood pressure (systolic/diastolic). Group 2 had significant decline in HR (3%) and diastolic blood pressure (6%), but not in systolic blood pressure and RPE. Group 1 had no significant changes in cardiorespiratory responses. All participants had significant improvements in HR (3%) and diastolic blood pressure (5%), but not in systolic blood pressure and RPE.

Supporting the findings at the present study Wang et al. (2015) found that a 10% increase of CRF after 10 weeks of training is enough to reduce systolic blood pressure (~13 mmHg). De Prada et al (2019) found that after training intervention, HR_{max} increased similarly in all their subject groups, but HR at VT1 improved only in one group. Heart rate, systolic and diastolic blood pressure at VT1 decreased after training intervention.

In the present study we found some improvements in cardiorespiratory functions (HR and diastolic BP) at moderate exercise intensity, but results varied between groups and individuals.

9.5 Associations between changes at anthropometric and cardiovascular values

At the present study there was statistical significance correlation in changes between weight, fat% and, BMI versus VO_2 at VT1, but not between any other anthropometrical and cardiovascular change. Therefore, changes in cardiorespiratory fitness seems to be mostly independent from changes in anthropometry.

As Gaesser and Angadi summarizes in their review (2021) that rationale for a weight-neutral strategy for obesity treatment should shift the focus from weight loss to increasing physical activity and improving cardiorespiratory fitness. The death risk linked with obesity is largely decreased or removed by moderate-to-high levels of cardiorespiratory fitness or physical activity. Most cardiometabolic risk markers linked with obesity can be upgraded with exercise training independent of weight loss and by a degree reached with weight-loss programs.

Supporting the findings at the present study Chávez-Guevara et al (2020) found in their meta-analysis a slight increase in VO_{2peak} after eight to sixteen weeks intervention, which was explained by the increase of absolute oxygen uptake (0.05–0.16 l/min) and not by body weight reduction, which supports the findings at the present study.

O`Donoghue et al (2020) wrote in their meta-analysis that until recently CRF has been overlooked as a potential modifier of the inverse association between obesity and mortality. Those studies researching the effectiveness of different exercise interventions for adults with obesity continue to focus too much on anthropometric measures to establish efficacy or effectiveness and not include CRF in their analyses. This also supports the findings at the present study.

9.6 General guidelines vs. individualized exercise prescription

Lehtonen et al (2022) noted in their critical review that the physical activity guidelines for the general population are designed to eliminate the rise of chronic diseases caused by inactivity and sedentariness. The present study supports their view that general guideline levels of cardiovascular, anthropometrical and exercise performance are insufficient and because of that, risk of life-long diseases remain. This study also supports their findings on that individual exercise prescriptions based on physiological thresholds are more effective in improving cardiovascular fitness in overweight/obese adults.

Thus, there is a need for an exercise prescription that targets the individual. Variability of CRF responses to exercise in a multitude of studies were explained by biological and methodological factors, and that is why modulation of exercise volume and intensity are the keys in improving prescription guidelines.

Lehtonen et al (2022) noticed that there is large individual variation in CRF responses to a training intervention with variation ranging from high responders to non-responders where no improvements are observed and even negative responders where a decrease in CRF can be seen. The present study supports these findings as we found that in Group 3 90% of participants could improve their exercise performance (W) at peak level, while at Group 2 73% and 69% at Group1 had improve. At VO_{2peak} 70% of participants in Group3 could improve their values, but only 57% in Group 2 and 46% in Group1. Individual changes were between +6% to -4%.

Kaseva et al (2022) found that personality characteristic or psychological wellbeing were not attributable to participant adherence in the present MoMaMO! study. Importantly, adherence remains a challenge to be reduced as also seen at the present study.

Individual interventions can be expensive because it requires laboratory resources and a different kind of expertise. For this reason, it is not possible for the general population approach. Lehtonen et al (2022) noted that population-wide exercise prescription guidelines must include self-assessment tools, such as the rate of perceived exertion (RPE) to analyze the exercise reflections of physiological thresholds.

Lehtonen et al (2022) made a proposal for a new framework to shape PA guidelines based on accessibility and effectiveness as part of a personalized exercise prescription that targets the individual (figure 27).

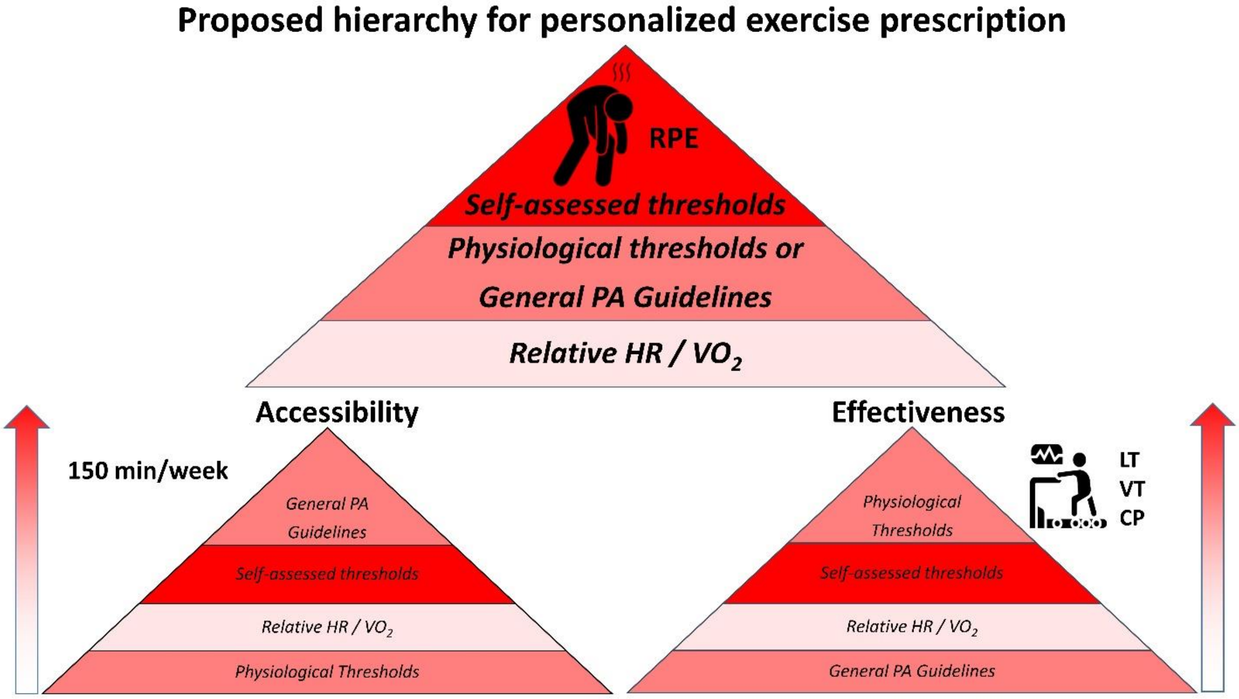


FIGURE 27. Proposed hierarchy for personalized exercise prescription (Lehtonen et al 2022).

9.7 Strengths and limitations

This kind of 3 month highly individualized intervention supported by professionals, which includes exercise tests, improved participants cardiorespiratory fitness substantially. However, it is expensive and needs a group of professionals to plan the interventions and the equipment to conduct the tests. Still, this kind of individual exercise programming can be a good method to solve the” epidemic” of overweight/obese as a global problem.

This study, monitoring participants trainings (effort and volume) and energy intake failed as planned, because of a lack of motivation to use any application. The use of applications motivates some participants, but not all. Technology alone is not the answer to get people motivated to increase their physical activity and improve their physical fitness. The present study highlights the need for personalized exercise prescription. There is a need for future research to minimize these limitations of monitoring training and energy intake during intervention.

The duration of this intervention was only 3 months because it is manageable through health care professionals and participants have the motivation to follow the prescriptions and take part in measurements.

10. CONCLUSIONS

The present study data demonstrates that highly individualized training prescription is more effective in improve cardiorespiratory fitness, exercise performance, and body composition in overweight and obese subjects than general guidelines.

The analysis identifies that this kind of individualized operational model can guide and support individuals progress towards a healthy lifestyle and improve cardiorespiratory fitness and exercise performance. Thus, improving participants daily ability to perform daily movements, delay fatigue and promote health benefits through accumulating physical activity remains a goal to strive for.

This study supports the results of previous studies in that technology alone is not the answer to get people motivated to increase their physical activity and improve their physical fitness.

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