Effectiveness of traditional- vs individualized power training based on force-velocity profiling on maximal power, rate of force development, myoelectric activity, and rate of myoelectric activity in older men

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SAMMENDRAG

INTRODUKSJON. Muskel power er rapportert å være en god indikator for funksjonell uavhengighet hos eldre. Individualisert power-trening basert på kraft-hastighets (K-h)-profilering har fått økende oppmerksomhet for å optimalisere muskel power utvikling. Målet med denne studien er å undersøke effekten av tradisjonell- vs individualisert power-trening basert på K-h-profilering på maksimal power (P_{max}), hurtighet på kraftutvikling (RFD), myoelektrisk aktivitet (EMG), og hurtighet på myoeletrisk aktivitet (RMA) hos eldre menn.

METODE. førti-ni eldre menn (år = 67.7±5.3) gjennomgikk fysisk testing før og etter en 10-ukers treningsintervensjon. Deltakerne ble randomisert til en individualisert (IT) eller en balansert treningsgruppe (BT) basert på K-h-profilering. K-h-profiler ble anskaffet fra Keiser-benpress. RFD, EMG, og RMA data ble målt under en isometrisk maksimal frivillig kontraksjon i kneekstensjon. P_{max} ble målt i kneekstensjon med gradvis økende belastning.

RESULTAT. Forskjeller innen gruppene: BT økte P_{max} (p=0.010), RFD $peak_{20}$ (p=0.023), RFD_{50} (p=0.030), RFD_{100} (p=0.006), og RFD_{200} (p=0.001). Ingen forskjeller observert for RFD_{30}. IT økte i peak EMG *rectus femoris* (p=0.008), mens alle gruppene økte i peak EMG *vastus lateralis* (BT: p=0.000; IT: p=0.000). Ingen økninger i $RMA_{30,\ 50,\ 100}$ *rectus femoris*, mens både BT og IT økte i RMA_{200} *rectus femoris* (p=0.035; p=0.000). Ingen økninger i $RMA_{30,\ 50}$ *vastus lateralis*, kun IT økte i RMA_{100} *vastus lateralis* (p=0.015), alle gruppene økte i RMA_{200} *vastus lateralis*. Gruppeforskjell mellom BT og IT ble kun observert i P_{max} (p=0.019), RFD_{50} (p=0.045), og RFD_{200} (p=0.012).

KONKLUSJON. Resultatene indikerer at en balansert treningstilnærming er mer fordelaktig for å forbedre P_{max} og RFD hos eldre menn, uten forskjeller i EMG. Basert på disse resultatene bør forsiktighet utvises ved anbefaling av en individualisert treningstilnærming basert på K-h-profilering hos eldre menn.

NØKKELORD. Power trening, kraft-hastighets profil, maksimal power, hurtighet på kraftutvikling, myoelektrisk aktivitet, hurtighet på myoelektrisk aktivitet, eldre menn

ABSTRACT

INTRODUCTION. Muscle power is reported to be a good indicator of functional independency in elderly. Individualized power-training based on force-velocity (F-v) profiling has received increasing attention for optimizing muscle power development. The aim of this study is to investigate effectiveness of traditional- vs individualized power-training based on F-v profiling on maximal power (P_{max}), rate of force development (RFD), myoelectric activity (EMG), and rate of myoelectric activity (RMA) in older men.

METHOD. Forty-nine older men (67.7±5.3 years) underwent physical testing before and after a 10-week training intervention. Subjects were randomized to an individualized (IT) or a balanced power training group (BT) based on F-v profiling. F-v profiles were obtained from Keiser leg-press. RFD, EMG, and RMA data were collected under an isometric maximum voluntary contraction in leg extension. P_{max} was measured with incremental loads in leg extension.

RESULTS. Within-group increases only with BT in P_{max} (p=0.010), peak RFD_{20} (p=0.023), RFD_{50} (p=0.030), RFD_{100} (p=0.006), and RFD_{200} (p=0.001). No within-group differences in RFD_{30}. Between-group difference only in P_{max}, RFD_{50}, and RFD_{200} between BT and IT (p=0.019; p=0.045; p=0.012, respectively). Within-group differences for all groups in peak EMG *vastus lateralis*, while only IT increased in peak EMG *rectus femoris*. Within-group difference with BT and IT in RMA_{200} *rectus femoris* and *vastus lateralis*. Within-group difference only with IT in RMA_{100} *vastus lateralis*. No differences in the other RMA intervals.

CONCLUSION. Results indicate balanced power training to be more beneficial for improving P_{max} and RFD in older men, with no difference in EMG. Use caution when recommending an individualized training approach based on F-v profiling in older men.

KEYWORDS. Power training, force-velocity profile, maximal power, rate of force development, myoelectric activity, rate of myoelectric activity, older men

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Abbreviations

1RM	1 repetition maximum
BT	Balanced power training group
CI	Confidence interval
CV	Coefficient of variation
DXA	Dual-energy x-ray absorptiometry
EMG	Electromyography
F-v	Force-velocity
H_0	Null hypothesis
ICC	Intraclass correlation coefficient
IT	Individualized power training group
MCIV	Maximum voluntary isometric contraction
NMJ	Neuromuscular junction
P_{max}	Maximal power output
RCT	Randomized controlled trial
RFD	Rate of force development
RIR	Repetitions in reserve
RMA	Rate of myoelectric activity
RMS	Root mean square
SD	Standard deviation

1.0 Introduction

The world's population is continually ageing, and the elderly population is growing in almost every country in the world. The growing number of older persons, aged 60 and above, is projected to accelerate in the coming decades, according to data from the UN (United Nations, 2015). The number of older persons is projected to grow from 901 million in 2015 to 1.4 billion in 2030, and the number of the oldest old, aged 80 and above, will increase from 125 million people in 2015 to 434 million people in 2050 (United Nations, 2015). The increase in the older persons population is pressing on to become one of the most significant social transformations of the twenty-first century. Population ageing is relevant for nearly all parts of society, particularly for the goals on ensuring healthy lives and well-being in the elderly (United Nations, 2015).

Physical functioning tends to decline as we get older, thus increasing incidence of disabilities related to walking and movement (Harvard University, 2016). Progressive loss of muscle strength, due to atrophy of muscle mass occurs naturally with advancing age. Reductions in muscle mass are primarily a consequence of losses of alpha motor neurons and the denervation of muscle fibers. Further, reductions in muscle cross-sectional area leads to a loss in ability to rapidly produce force, otherwise known as muscle power (Lohne-Seiler, Torstveit & Anderssen, 2013). Muscle power is reported to be positively associated with the ability to perform everyday activities and may be a predictor of functional dependency more than muscle strength is, seeing as muscle power declines more rapidly than muscle strength with advancing age (Lohne-Seiler et al., 2013). Voluntary movements requiring relatively high force production are likely to require rapid execution in day-to-day living, such as in trip recovery. Therefore, muscle power may be more useful in an aging population than isometric and isokinetic strength (Perkin, McGuigan, Thompson & Stokes, 2018).

Since muscle power is the product of force and velocity, and that each individual is more likely to either be force dominant or velocity dominant, a more individualized approach to power training may prove beneficial for deterring decreases in muscle power in older adults compared with the traditional approach (Alcazar et al., 2018). In recent past, interest in assessing and evaluating the force-velocity (F-v) relationship in elderly has been increasingly growing. Results of a recent study assessing F-v relationship in elderly adults, showed that both quality of life and physical functioning as well as frailty was related to individual differences in the F-v relationship (Alcazar et al., 2018). Furthermore, they suggested that interventions aimed at reversing age- and/or disuse-related impairments of muscle power evaluate the specific responsible mechanisms (force vs. velocity deficits) and act accordingly (Alcazar et al., 2018).

1.1 Overall aim and hypothesis

To the authors knowledge, there are currently no studies exploring the effectiveness of an individualized power training program based on F-v profiling in elderly adults. Therefore, the aim of this study is to investigate which training approach; traditional strength training or individualized power training based on F-v profiling is most effective to improving maximal power, rate of force development, myoelectric activity, and rate of myoelectric activity in elderly men.

1.1.1 Hypothesis

“Individualized power training based on F-v profiling is more effective in increasing maximal power, rate of force development, myoelectric activity, and rate of myoelectric activity in older men compared with a balanced power approach.”

2.0 Theoretical framework

2.1 Sarcopenia

Although there are slightly different variations in definition, sarcopenia may be described as age-associated loss of skeletal muscle mass and function, and the causes are multifactorial and can include disuse, change in endocrine function, and inflammation among more (Lynch, 2011). Evidence suggest that skeletal muscle mass and strength decline in a linear fashion, and that by the age of 80-90 years old, up to 50% of mass may be lost (Walston, 2012). Peak muscle strength is shown to usually plateau sometime in the 30s and decline at a steady pace thereafter (Delmonico & Beck, 2016). Decreases in muscle mass is about 1 to 2% annually by the 5th decade of life and declines in muscle strength is suggested to be about 1.5% per year after aged 60 (Ogawa, Yakabe & Akishita, 2016). In addition, muscle power has been shown to decrease about 3 to 4% faster than muscle strength and should be of concern since muscle power better explains variance in physical functioning in older adults than muscle strength alone (Delmonico & Beck, 2016). While type I muscle fiber size seems to remain less affected during ageing, type II muscle fibers has shown to be 10 to 40% less observed in older adults compared with younger controls (Nilwik et al., 2013). Type II muscle fibers have demonstrated to have at least 6 to 10 times greater peak power compared with type I fibers (Wilson et al., 2012). This decline in muscle power in older adults heightens the risk potential for accidents due to muscle weakness, fatigue, and poor balance (McArdle, Katch & Katch, 2015). Therefore, improving skeletal muscle power has been suggested to be the main target in developing resistance training interventions aimed at enhancing physical function and preserving independence later in life (Alcazar, Guadalupe-Grau, García-García, Ara & Alegre, 2017).

2.2 Skeletal muscle power

Muscle power is defined as the product of force and distance in a specified time and can be calculated using equations depending on direction. For linear motion: power = force x distance / time, and for rotational motion: power = moment x angular displacement / time. When applied to human exercise, muscle power = force x velocity of contraction (Everett & Kell, 2010). Therefore, one might think of power as how quickly or slowly muscle work is done (McGinnis, 2005).

2.2.1 Muscle power, ageing and physical capacity

Age-related reductions in skeletal muscle power is greater compared with losses in skeletal muscle mass and strength and are more detrimental to overall health. Skelton et al. has one of the earliest reported measurements of age-related loss of skeletal muscle power in 1994. They reported that starting at age 40, adults lose 3 to 4% of their original skeletal muscle power each year (Bouchard, 2020). Multiple studies have since investigated age-related loss of skeletal muscle power, and results vary. However, longitudinal studies have demonstrated the best evidence, indicating a 1.2 to 2.9% loss of skeletal muscle power per year due to ageing (Bouchard, 2020). Falling is a major threat for elderly, therefore, mass, strength and power in the lower extremities is critical for independent functioning in later life (Trombetti et al., 2016). Research by Bassey et al. in 1992 found leg extensor peak power to be predictive of chair rise performance, stair climbing, and gait speed among older adults, and has since been considered groundbreaking.

2.3 Myoelectric activity

Skeletal muscles work under voluntary control, meaning they will contract or relax when they receive electrical signals (Xiao, 2018). *Myos* is latin for muscle (Nigro & Politano, 2015), therefore, electrical activity from the nervous system that activates muscles (myos) is termed myoelectrical activity (Devasahayam, 2000). Age-related reductions in skeletal muscle strength and power is not only limited to changes in skeletal muscle systems but can also be attributed to changes in the nervous systems (Bouchard, 2020). Older adults experience reductions in peak force and time to reach peak force due to impairments in neuromuscular activation, leading to decreased skeletal muscle power (Bouchard, 2020). Age-related changes in the nervous system include loss of motor neurons and demyelination of axons in both the central and the peripheral nervous systems. These changes affect neuronal ability to conduct and transmit motor commands to skeletal muscles (Bouchard, 2020).

2.3.1 Motor unit recruitment

Skeletal muscle fibers are controlled by alpha motor neurons in the anterior horns of the spinal cord and in motor nuclei of the origin of the cranial nerves. A motor unit is the neuron and the specific muscle fibers that it innervates (Xiao, 2018). Axons of neurons branch as they adjoin muscles, creating terminal branches which end on individual muscle fibers (figure 1) (Xiao, 2018). Muscles and nerves interact at the neuromuscular junction (NMJ), a synaptic link through which the peripheral nervous system contacts skeletal muscle fibers and regulates vital processes, such as voluntary movements and respiration (Lepore, Casola, Dobrowolny & Musarò, 2019). A presynaptic cell is the neuron that carries action potentials, whereas a postsynaptic cell is the muscle cell receiving it (Xiao, 2018). Force produced by skeletal muscles depends on the number of motor units recruited and the discharge rate of action potentials innervating each active motor unit (Hunter, Pereira & Keenan, 2016). Motor units are recruited according to the size principle, meaning relatively small alpha-motoneurons innervating type I fibers are initially triggered at low force levels, whereas increasingly larger alpha-motoneurons that trigger type IIa and IIx fibers usually activates at higher force thresholds (Cormie, McGuigan & Newton, 2011). A motor unit will fail to contribute to force generation when a motor neuron and the innervated fibers are lost (Gonzalez-Freire, de Cabo, Studenski & Ferrucci, 2014). Research has provided clear evidence that changes in NMJ occur with advancing age. Nerve terminal area and the number of post-synaptic folds are reduced leading to a functional impairment of NMJ's post-synaptic response (Gonzalez-Freire et al., 2014). Age-related loss of neurons is gradual, and ultimately irreversible (Gonzalez-Freire et al., 2014).

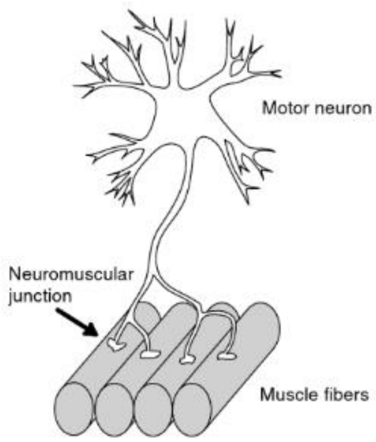

Figure 1 From Hof, 2010. A representation of all the elements of a motor unit. The neuromuscular junction is the communicative link between the neuron and the muscle fibers.

2.3.2 Firing frequency

Signaling frequency from the central nervous system to the motor unit is an integral part of muscle power production. Production of muscle power becomes greater with increasing signal frequency due to a stepwise increase in firing rate of motor units (Kraemer & Looney, 2012). Firing frequency of motor units (rate of myoelectric activity) is the rate of neural impulses transmitted from alpha-motoneurons to the muscle fibers (Cormie et al., 2011). If signal frequency exceeds a sufficiently high velocity, muscle fibers cannot relax in-between, and may therefore be re-stimulated while previous contractions is still occurring. Contractions will then merge at the peak of the previous contraction, resulting in a stronger and more powerful contraction (Kraemer & Looney, 2012). By estimation, when firing frequency of motor units increase from its minimum to its maximum, contraction force can increase by 300 to 1500% (Cormie et al., 2011). Moreover, firing frequency also affect rate of force development (RFD) of muscle contraction. Motor units have been reported to start firing at extremely high frequencies, followed by an abrupt decrease (Cormie et al., 2011). While only sustained for a short period of time, the initial frequency of the signal is assumed to be correlated with an increase in the number of doublets (a pair of action potentials at short intervals) discharged, thus resulting in an increased RFD (Cormie et al., 2011).

2.4 Rate of force development

RFD is commonly defined as the speed at which contractile elements of the muscle develop force (Aagaard, Simonsen, Andersen, Magnusson & Dyhre.Poulsen, 2002). RFD is derived either from the slope of the force-time curve (Δforce/Δtime) (figure 2) in isolated muscle preparations or calculated as the slope of the joint moment-time curve (Δmoment/Δtime) for intact joint actions (Aagaard et al., 2002). RFD reflects the rate at which muscle tension can be developed and is important in movements that require rapid action such as sprinting, jumping, or reversing a fall (Rodriguez-Rosell et al., 2018). Movements are classified as either slow (>250ms) or fast (<250ms) (Turner & Jeffreys, 2010). Muscles typically take a longer time (≥300ms) to reach maximum force, therefore, during fast limb movements, the short contraction time may not be enough to reach maximal muscle force. Consequently, any improvement in contractile RFD is highly significant because it enables the early phase of muscle contraction to achieve a higher level of muscle power (Aagaard et al., 2002). Most studies have indicated that RFD is the most precise term for rapid rise in force production (Rodriguez-Rosell et al., 2018). RFD enhances the quality of life in elderly (Hernández-Davó & Sabido, 2014), for instance, an elderly person can decrease risk of falling by being able to exert a rapid increase in muscle force (Aagaard et al., 2002). A plethora of RFD measuring strategies have been developed, among them are time-interval RFD and peak/maximal RFD (Haff, Ruben, Lider, Twine & Cormie, 2015). Time-interval RFD is calculated at various time intervals (e.g. 0-30ms, 0-50ms, 0-100ms, 0-200ms) by dividing the force at the end of the time interval with the duration of the time interval (Haff et al., 2015). Peak RFD is the largest amount of RFD produced during a movement. The most common strategy to identify peak RFD is during various sampling windows (5ms, 10ms, 20ms etc) (Haff et al., 2015). For example, by measuring peak RFD every 20ms (0-20ms, 20-40ms, 40-60ms etc.) and simply identify the largest recorded value (Haff et al., 2015).

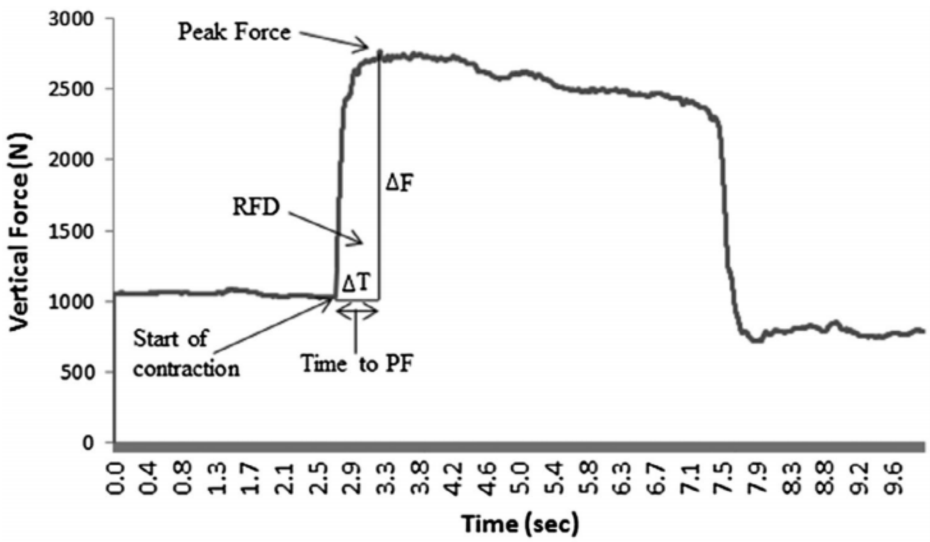

Figure 2 From Brady, 2018. Force-time curve detailing start of contraction, peak force, RFD, change in force and time (ΔF/ΔT), and time to peak force.

2.5 Assessing neuromuscular function

2.5.1 Electromyography

When a muscle is activated, an electrical discharge (myoelectric signal) is produced, which can be measured directly via electrodes (Bhattacharya & McGlothlin, 2012). These myoelectric signals yield information about the intensity and duration of a muscle contraction (Bhattacharya & McGlothlin, 2012). By using a needle and fine wire electrodes one can measure myoelectric activity of single motor units, however, when measuring myoelectric activity of muscles, surface electrodes are typically used (Bhattacharya & McGlothlin, 2012). Skeletal muscle activity is normally measured during voluntary muscle actions and by placing surface electrodes close to the muscle of interest (Devasahayam, 2000). Bipolar recording is usually preferred in EMG recording, in which two electrodes are placed near the muscle and the differential signal between them is recorded and observed (Devasahayam, 2000). The measured signal reflects the summation of all activated motor units within the electrode area (Bhattacharya & McGlothlin, 2012).

2.6 Resistance exercise training in older adults

There is a large body of evidence suggesting resistance training to be an effective strategy to counteracting many of the undesirable physical consequences of ageing (Fragala et al., 2019). However, there are currently no standardized resistance training guidelines for improving muscle strength and power among older adults. Still, resistance training has proven to be safe and viable in this population, thus the general public guidelines by the American College of Sports Medicine (ACSM) may be suitable for older adults (Bouchard, 2020). ACSM's current recommendation on frequency for strength training exercise is 2 to 3 days per week, but research has shown that as little as 1 day per week of strength training improved strength and physical function among elders (Seguin & Nelson, 2003). Research has provided strong evidence that resistance training for elderly can help mitigate losses of neuromuscular function and functional capacity, notably with the inclusion of power training exercise (Fragala et al., 2019).

2.6.1 Power training and older adults

Power training is characterized by performing traditional resistance training exercises at the highest possible velocity during the concentric phase of the lift and spending approximately 2 to 3 seconds on the eccentric phase (Hazell, Kenno & Jakobi, 2007). Marsh et al. reported that power training is safe and effective at increasing strength and power of lower extremities in older adults (Marsh, Miller, Rejeski, Hutton & Kritchevsky, 2009).

2.7 Force-velocity relationship

Force multiplied by velocity equals power, and thus underpin the ability to be powerful. However, it is entirely possible for two individuals to display resembling power output even if their force and velocity capacities differ (Samozino et al., 2013). Theoretically, individuals are skewed toward either strength (force) or speed (velocity), which can hinder them in, for example, an explosive jumping movement. Determining whether an individual is force- or velocity-deficient may be advantageous (Jiménez-Reyes, Samozino, Brughelli & Morin, 2017). The force-velocity (F-v) relationship is a representation of the inverse relationship between force and velocity (Cormie et al., 2011), meaning, as the velocity of a concentric muscle movement increases, the force produced will simultaneously decrease (Kraemer & Looney, 2012). This can be explained by the fixed amount of time it takes for cross-bridges to be attached and detached. The total number of cross-bridges attached decreases with increasing velocity of muscle contraction (Cormie et al., 2011). Maximal power will therefore occur at an optimal combination of submaximal force and velocity values (Cormie et al., 2011).

2.7.1 Force-velocity profile

A force-velocity profile (F-v profile) shows the proportion between an individual's maximal force and velocity capabilities and can be determined by the slope of the F-v relationship (Samozino et al., 2013). An ideal/optimal F-v profile exists for every individual, representing the best balance between their force and velocity capacities (figure 3) (Samozino et al., 2013). For any given individual, relative contrast between actual and optimal F-v profile mirrors the magnitude and direction of the unevenness between force and velocity (F-v imbalance) (Jiménez-Reyes et al., 2017). Evaluation of F-v imbalance would theoretically help improve effectiveness of a training intervention aimed at improving power production, simply because one would customize training to focus on individual needs and effectively shift the actual profile toward the optimal profile (Jiménez-Reyes et al., 2017).

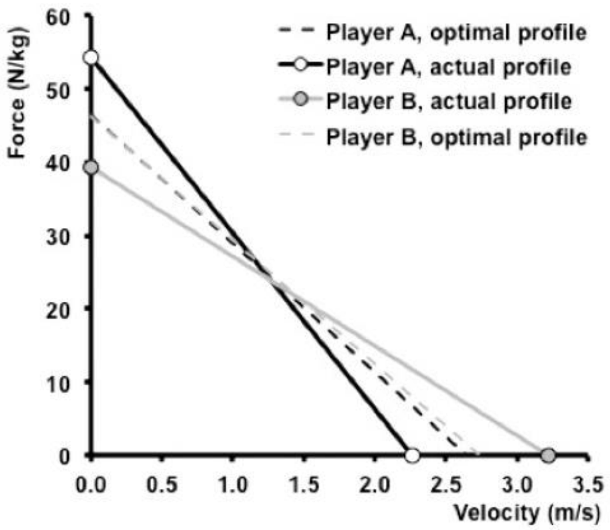

Figure 3 From Morin, 2015. A representation of actual and optimal F-v profiles of 2 elite athletes. Player A is shown to be force dominant, whereas player B is velocity dominant.

2.7.2 Force-velocity profiling in older adults

By evaluating F-v relationships in older adults one might identify neuromuscular deficits and design training interventions to help overcome them, thus enhancing physical performance (Alcazar et al., 2017). Evaluation of F-v relationships can be isotonic or isokinetic (Alcazar et al., 2017). Isotonic evaluation involves registering movement velocity exerted against increasing loads, whereas isokinetic evaluation means measuring force exerted at different constant velocities (Alcazar et al., 2017). Isokinetic evaluation is less advantageous since isokinetic movements are a rare occurrence in day-to-day functional tasks (Alcazar et al., 2017). A study from 2017 by Alcazar et al. concluded that registering mean force and velocity from multiple increasing loads is valid, reliable and safe for assessing F-v relationships in older adults (Alcazar et al., 2017). In a study from 2017 investigating individualized resistance training based of F-v profiling in trained athletes, evidence suggest that targeted resistance training based on individual F-v profiling is an effective way to improve jumping performance in trained athletes (Jiménez-Reyes et al., 2017). Since jumping performance is highly influenced by the ability to produce muscle power in a short time frame (Cormie et al., 2011), similar findings may emerge in an older population.

3.0 Method

3.1 Study design

This master thesis is part of a larger research project conducted by the University of Agder at the "Faculty of Health- and Sport Science". Only the tests pertaining to this master thesis´ research question will be presented.

The design of this study is a randomized controlled trial, designed to measure the effects of a traditional power training intervention versus an individualized power training intervention in healthy elderly men. A pilot test was done prior to baseline testing to evaluate the feasibility of the proposed test battery. The pilot test included a total of five elderly men, aged 60-78. Subjects were divided into groups of two and three in order to examine which would be most effective to use during pre- and post-testing. It was determined that groups of three subjects would be most time efficient. Furthermore, training programs were also tested to see if subjects would be able to complete all the different training exercises. Upon completion, it was decided that the reverse lunge exercise would replace the Bulgarian split squat due to subjects not being able to perform the exercise sufficiently.

Prior to starting training intervention, each subject had to complete one week of familiarization testing, and two weeks of baseline testing in order to minimize any potential learning effect. After baseline testing, subjects were randomized to one of two intervention groups, either a balanced training group or an individualized training group based on their deficiencies in either strength or speed (see chapter 3.2). Before the intervention could begin, subjects had to attend two sessions of familiarization in order to learn the different exercises in the training program. The training intervention lasted for a duration of 10 weeks, and subjects trained two days per week. After five weeks of training, the training load was adjusted (see chapter 3.4). Upon completing the 10 weeks of training, subjects had to complete two rounds of post-testing with a week of rest in-between (Figure 4).

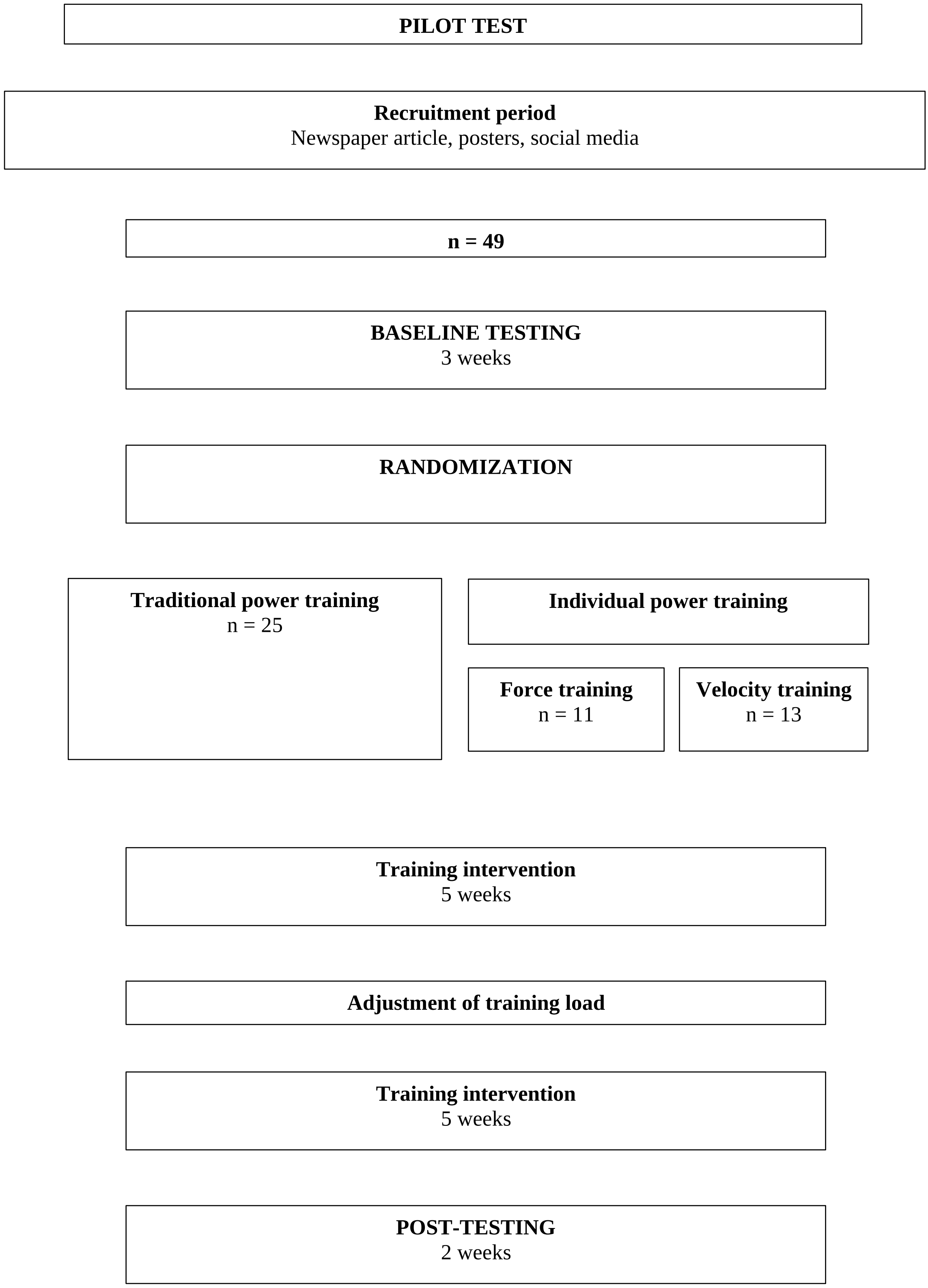

Figure 4 Flowchart illustrating the progression of the study, including pilot testing, recruitment, randomization, training intervention, midway adjustment, and all measuring points throughout the present study.

3.2 Subjects

Target subjects are healthy home-dwelling adult males, aged >60 years old. In order to determine sample size needed to detect any effect at the desired level of significance, a statistical power analysis was performed before recruitment and data collection. In order to detect a difference with 80% power at 5% α-level, we needed to include 20 subjects in each training group to find 8% difference between groups. Calculations are based on % change in lower body power as a dependent variable (Straight et al., 2016; Jiménez-Reyes et al., 2017). Furthermore, to account for any potential dropouts, 25 subjects in each group was deemed necessary. Subsequently, a target sample of 65 subjects were determined to be appropriate, including 15 subjects in a control group.

Subjects were recruited in august 2019 by way of different strategies, which included: a newspaper article in the local newspaper (attachment 1), posters distributed in the immediate area (attachment 2) and by social media. A gathering was also arranged during this time for all potential subjects with the purpose of presenting information, both orally and in written form, concerning the project (attachment 3).

Subjects had to meet certain criteria in order to be included (table 1), these are: male, aged >60, provide a written medical clearance from their personal physician (attachment 7). Subjects were excluded if they had any illnesses or injuries preventing them from safely participating in heavy resistance training, or if they had participated in systematic strength training six months prior to the study (table 1). Systematic or progressive strength training is defined as the continued improvement in a desired variable over time until the target goal has been achieved. Repetitions, sets, exercises, number of exercises, and frequency depends on the desired outcome in variables such as muscular strength, power, hypertrophy etc. (Kraemer et al., 2009). Meaning, subjects that trained strength training two or more times actively per week were excluded from the study. A total of 56 subjects in Kristiansand and the surrounding area aged 60-83 years old were recruited for this study.

Table 1 List of inclusion and exclusion criteria for participation.

Inclusion criteria	Exclusion criteria
1. Male 2. >60 years old 3. No systematic resistance training 6 months prior to pre-testing 4. Medical clearance from personal physician	1. Illnesses or injuries preventing participation in testing and training 2. Participation in other forms of resistance training

Training groups were a balanced power training group (BT), and an individualized power training group (IT). To prevent imbalance between training groups due to their different impact on outcomes, a stratified randomization was used. Subjects were stratified randomized into either the BT group or the IT group based on their F-v profile in Keiser leg-press. Subjects were rated based on their mean slope in Keiser leg-press, with the upper half considered as force dominant and the lower half as velocity dominant. Subjects were then randomized into either the BT group or the IT group using a random number generator. Subjects randomized to the IT training group received a power training program dependent on their F-v profiles, meaning they would train on their deficit. A subject in the IT group considered force dominant would train velocity, and a velocity dominant subject would train force. Subjects in the BT group received a comparable power training program independent of their F-v profiles (see chapter 3.4.1). Seven subjects would later dropout due to either injury, sickness or other work-related issues. Four dropouts were from the IT group, while the other three were from the BT group, bringing the total number of subjects down to 49 (table 2).

Table 2 Number of subjects in each training group before and after accounting for dropouts.

Groups	**n**	**Dropouts**	**n**
BT	28	3	25
IT	28	4	24
- Force deficient training group	14	3	11
- Velocity deficient training group	14	1	13
Total	56	7	49

3.3 Ethical considerations

The study has been approved by the Norwegian Centre for Research Data (NSD) (attachment 5), and permission was granted by the local ethics committee for the Faculty of Health and Sport Sciences at the University of Agder (FEK) to undertake this particular master thesis (attachment 6). All subjects were informed orally and in written form (attachment 3) of discomforts that may occur during the study such as fasting prior to measurement of body composition, and testing, and in some cases training to exhaustion, as well as risks associated with resistance training. Participation was voluntary and subjects could at any moment withdraw, if they wished to do so, without stating any reason. Written consent was obtained from all subjects (attachment 4).

Collected data were anonymized and stored safely in digital form, only accessible to research personnel. Private subject information was also anonymized using person specific codes and could not be linked to the person's identity. All data was exterminated when no longer useful. By giving a written consent, subjects had agreed to the publication of the anonymized data in journals, lectures and congresses. Each subject had a right to feedback of their own data, thus, test results was distributed to each subject after the analyzing process.
The present study has been operated in accordance with the Declaration of Helsinki.

3.4 Training intervention

The training period lasted for 10 weeks, and subjects had to attend two sessions per week, for a total of 20 sessions. Subjects either trained Monday and Wednesday in the evening, or Tuesday and Thursday in the morning. Friday afternoon was used as a buffer for subjects who missed a session that week. Subject participation was recorded for each session, and subjects could be absent from training four times in total. If exceeded, the subject was excluded from the study. Subjects each received their own individual training sheet on which to log repetitions and sets completed for each exercise. Training sheets were handed out at the start and stored safely away at the end of each session by training personnel. Training load in each exercise was estimated from baseline results in Keiser leg-press for lower extremities, and bench press for upper extremities. Estimation of training load occurred after baseline testing, and prior to the training period. Training load was adjusted properly in the first week of training during familiarization using the repetitions in reserve method (RIR) (Helms, Cronin & Storey, 2016). RIR is a strategy that attempts to quantify perceived exertion of strength exercise. If subjects that trained force (velocity dominant subjects in IT, and BT program 2), performed more than 10 repetitions, the training load was increased. Likewise, if subjects that trained velocity (force dominant subjects in IT, and BT program 1) performed more than 7-8 repetitions, the training load was increased. Rest period was set to 2-3 minutes between each set. After five weeks of training, the load was adjusted once more using RIR to accommodate for adaptation. However, subjects training velocity did not increase training load during this time. Instead, training personnel measured velocity using a linear encoder connected to a laptop with dedicated software (MuscleLab; Ergotest, Langesund, Norway). This way, subjects were motivated to increase their velocity with each repetition performed. Subjects trained with close control of adherence in order to ensure their safety, provide guidance, and motivate them. Therefore, a minimum of one training instructor was always present during training. Subjects had knowledge of which training group they belonged to. Subjects had to warm up before each session and consisted of both a general and an exercise specific warm up. The general warm up was focused on light, low intensity running up a flight of stairs for 5-10 minutes, followed by a set of different dynamic stretches. The exercise specific warm up focused on technique and was performed with a lower intensity (50% of training load) as an additional set in each exercise. Each session concluded with a collective core training in order to strengthen core muscles and build comradery between subjects.

3.4.1 Training programs

Training programs were split into two separate days, one for each session, customized with their own sets of exercises based on training groups. Velocity dominant subjects in the IT group trained with a focus on heavy lifting with an intensity of 70-80% of 1 repetition maximum (1RM), and 6-8 repetitions (table 5 & 6). Force dominant subjects in the IT group trained with a focus on velocity with a lower intensity, usually 20-50% of 1RM, and 5 repetitions (table 7 & 8). BT combined force training and velocity training with no individual specificity (table 3 & 4). All subjects were instructed to perform each repetition as explosively as possible, meaning maximum velocity during the concentric movement of the lift.

Table 3 Traditional power training program 1, RIR = repetitions in reserve.

Exercise	*Reps*	*Sets*	*Load (%1RM)*	*RIR*	*Rest*	*Comment*
Sit-to-stand	5	4	50%	x	2-3 min	Weight vest/dumbbells
Medicine ball press	5	4	20%	x	2-3 min	Lying press/throw
Rowing	5	4	20%	x	2-3 min	Dumbbells
Squat jump	5	4	-20%	x	2-3 min	De-load (resistance band)
Shoulder press	5	4	50%	x	2-3 min	Dumbbells
Core exercises	x	x	x	x	x	Varied

Table 4 Traditional power training program 2, RIR = repetitions in reserve.

Exercise	*Reps*	*Sets*	*Load (%1RM)*	*RIR*	*Rest*	*Comment*
Leg press	6	3	80%	1-2	2-3 min	Apparatus
Bench press	6	3	80%	1-2	2-3 min	Apparatus
Lunge	5	3	50%	5-8	2-3 min	Weight vest/dumbbells
Pull-down	6	3	80%	1-2	2-3 min	Apparatus
Leg curl	6	3	80%	1-2	2-3 min	Apparatus
Core exercises	x	x	x	x	x	Varied

Table 5 Individualized force training program 1, RIR = repetitions in reserve.

Exercise	*Reps*	*Sets*	*Load (%1RM)*	*RIR*	*Rest*	*Comment*
Squat	8	3	80%	1-2	2-3 min	Barbell
Chest press	8	3	80%	1-2	2-3 min	Apparatus
Step up	6	3	80%	1-2	2-3 min	Dumbbells
Rowing	8	3	80%	1-2	2-3 min	Apparatus
Shoulder press	8	3	80%	1-2	2-3 min	Dumbbells
Core exercises	x	x	x	x	x	Varied

Table 6 Individualized force training program 2, RIR = repetitions in reserve.

Exercise	*Reps*	*Sets*	*Load (%1RM)*	*RIR*	*Rest*	*Comment*
Leg press	6	3	80%	1-2	2-3 min	Apparatus
Bench press	6	3	80%	1-2	2-3 min	Barbell
Lunge	5	3	80%	1-2	2-3 min	Dumbbells
Pull down	6	3	80%	1-2	2-3 min	Apparatus
Leg curl	6	3	80%	1-2	2-3 min	Apparatus
Core exercises	x	x	x	x	x	Varied

Table 7 Individualized velocity training program 1, RIR = repetitions in reserve.

Exercise	*Reps*	*Sets*	*Load (%1RM)*	*RIR*	*Rest*	*Comment*
Medicine ball press	5	4	20%	x	2-3 min	Lying press/throw
Rowing	5	4	20%	x	2-3 min	Dumbbells
Squat jump	5	4	-20%	x	2-3 min	De-load (resistance band)
Shoulder press	5	4	40%	x	2-3 min	Dumbbells
Leg curl	5	4	50%	x	2-3 min	Apparatus
Core exercises	x	x	x	x	x	Varied

Table 8 Individualized velocity training program 2, RIR = repetitions in reserve.

Exercise	*Reps*	*Sets*	*Load (%1RM)*	*RIR*	*Rest*	*Comment*
Sit-to-stand	5	4	Bodyweight	x	2-3 min	Weight vest/dumbbells
Bench press	5	4	50%	x	2-3 min	Lying press/throw
Lunge	5	4	50%	x	2-3 min	Dumbbells
Pull down	5	4	50%	x	2-3 min	Overload (resistance band)
Rowing	5	4	50%	x	2-3 min	Dumbbells
Core exercises	x	x	x	x	x	Varied

3.5 Test procedure and measurements

The test protocol consisted of a fasted dual-energy X-ray absorptiometry, unilateral leg-press power test, leg extension power test, and EMG and RFD measurements in leg extension. Leg-press power test is presented in this thesis due to its role in the stratified randomization of subjects in this study.

3.5.1 Dual-energy X-ray absorptiometry (DXA)

Body composition was measured by dual-energy X-ray absorptiometry using a Lunar Prodigy (model 8743; GE Lunar Corporation, Madison, WI, USA). Subjects arriving for testing before noon, had to show up in a fasted state (no food or liquid consumption), whereas subjects arriving in the afternoon, were instructed to not eat or drink the last four hours before testing. Height and weight for each subject was recorded before the test, and bodily ornaments such as jewelry and watches were removed. Subjects were instructed to lay down on the DXA machine with legs straight and internally rotated, and with their arms slightly away and alongside the body. Subjects were scanned from head-to-toe in a supine position, measuring fat and lean muscle mass in arms, legs, and trunk.

3.5.2 Leg press power test

To complete a force-velocity profiling, Keiser Pneumatic Leg-Press was used (Keiser Sports Health Equipment Inc., Fresno, CA, USA). The knee angle was set to approximately 90˚ for all subjects using a Baseline 14-inch Stainless Steel 360 Degree Goniometer. During familiarization, testing procedure consisted of a six repetitions power test in a seated position with feet flat on each foot plate. The test consisted of five different incremental loads, with two attempts per load. Rest periods was set to 60-second intervals for the first two loads, 90-second interval for the third load, and 120-second intervals for the fourth and fifth loads. Subjects were instructed to "push as hard and fast as possible" continuing for all repetitions or until failure. Furthermore, a 1RM for each subject had to be recorded. If subjects did not reach 1RM in the first five loads, the load was increased by 5-10kg until 1RM was found.
During baseline testing 1 and 2, the ten repetitions maximal power test in Keiser Pneumatic Leg-Press was used (Redden, 2018). The load was calculated from 1RM achieved during familiarization (table 9). Beginning at a low resistance, subjects were instructed to push "as hard and as fast as possible" continuing for 10 repetitions (incremental increase in load per repetition) or until failure. Subjects were encouraged to rest their legs in between repetitions

by removing their feet from the foot plates as the load got heavier. Subjects were always aware of the next load they were attempting. For each effort, peak force, velocity and power were recorded for each leg. Upon completing the force-velocity profiling, subjects got 2-3 minutes of rest before attempting a new 1RM. 1RM was achieved by progressively increasing the resistance by 5-10kg until they were unable to complete another lift. When a subject failed to complete a lift, the load was reduced by 5kg at a time in order to accurately determine their 1RM. Resistance started at the maximum resistance from the 10 repetitions maximal power test. Subjects received 2 minutes of passive rest between each completed lift. Resistance for the 10 repetitions maximal power test for baseline 2 was calculated using 1RM from baseline 1. Test-retest reliability of slope was examined between pre-test 1 and 2 (CV=9.6%; ICC=0.81).

Table 9 Example of repetitions and load in Keiser leg press power test based on 200kg 1RM.

Repetition number	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Resistance based on 200kg 1RM	33	51	70	88	106	126	144	162	181	199
Rest period (s)	3.0	4.2	5.8	8.1	11.4	15.8	22.1	30.8	43.0	60.0

3.5.3 Leg extension power test

Maximal power (P_{max}) was measured in a single-joint movement, using a unilateral leg extension machine (G200 Knee Extension Machine, David Health Solutions Ltd., Helsinki, Finland). A similar leg extension procedure has been used to assess lower extremity muscle power in elders (Callahan et al., 2007). Leg extension machine was adjusted to 90˚ at the knee joint for all subjects, and they were seated and strapped in at the hips, torso and shins to prevent any aided movement. Testing procedure, outlined in table 10, consisted of a low velocity three-repetition warm-up, followed by three repetitions of high velocity, all at a low resistance (15 kg). After warming up, subjects performed two consecutive repetitions per leg, per load, starting with the right leg, and then the left leg. Subjects had to complete four incremental loads in total, starting at 15kg, and increasing to 20kg, 30kg, and finally 40kg. Subjects received 1-minute of passive rest between loads. Subjects were instructed to perform each repetition with maximum intended force and velocity, and to have a brief rest between the two repetitions. Test-retest reliability of P_{max} was examined between pre-test 1 and 2 (CV=4%; ICC=0.91).

Table 10 Illustration of test procedure for leg extension power test, including repetitions, load, and rest period.

Repetition number	Warm-up 1st	Warm-up 2nd	Warm-up 3rd	1st	2nd	3rd	4th
Resistance (kg)	15 kg	15 kg	15 kg	15 kg	20 kg	30 kg	40 kg
Rest period (s)	10.0	10.0	10.0	60.0	60.0	60.0	60.0

3.5.4 Electromyography and Rate of Force Development measurements

A wireless EMG module (MuscleLab: Ergotest Innovation AS, Stathelle, Norway) and a surface electrode (Ambu BlueSensor M, Ballerup, Denmark) was used to measure myoelectrical activity of the *rectus femoris* and *vastus lateralis* muscle on both legs. A similar test procedure has been described elsewhere (Alkner et al., 1999). Myoelectric activity was measured in a seated position with the knee angle at 90˚ in a unilateral leg extension machine (G200 Knee Extension Machine, David Health Solutions Ltd., Helsinki, Finland). Hips, torso and shins were strapped in to prevent aided movement and ensure proper technique. To measure and evaluate myoelectric activity, subjects performed a maximum voluntary isometric contraction (MVIC). Peak EMG is based on the square root calculation (RMS), and reflects the mean power of the signal (+/- 250ms from peak measurement/signal). Subjects performed 3 repetitions of MVIC per leg, starting with the right leg. Each repetition was to be executed with maximum force and velocity and be held for 3-5 seconds. To prevent fatigue, subjects received 1-2 minutes of passive rest between each repetition. Two electrodes were attached side-by-side to each of the muscles. In order to gather EMG data as accurately as possible, the electrodes were attached after sites were shaven and cleaned. Sensor site was determined using a marker during ultrasound. Frequency of the EMG signal was set to 20-500 Hz bandwidth and sampling frequency was 200 Hz. RFD was measured simultaneously from each repetition in the same test procedure by attaching a force sensor to the machine lever arm, connected to a desktop PC, using dedicated software (MuscleLab: Ergotest Innovation AS, Stathelle, Norway). The test-retest reliability for all measures was examined between pre-test 1 and 2. Peak EMG *rectus femoris* (CV=16%; ICC=0.69), Peak EMG *vastus lateralis* (CV=15%; ICC=0.75), RMA *rectus femoris* 0-30 (CV=33%; ICC=0.35), RMA *rectus femoris* 0-50 (CV=35%; ICC=0.38), RMA *rectus femoris* 0-100 (CV=38%; ICC=0.38), RMA *rectus femoris* 0-200 (CV=34%; ICC=0.35), RMA *vastus lateralis* 0-30 (CV=39%; ICC=0.35), RMA *vastus lateralis* 0-50 (CV=39%; ICC=0.52), RMA *vastus lateralis* 0-100 (CV=34%; ICC=0.50), RMA *vastus lateralis* 0-200 (CV=25%; ICC=0.46), RFD $peak_{20}$ (CV=13%;

ICC=0.82), RFD 0-30 (CV=88%; ICC=0.42), RFD 0-50 (CV=79%; ICC=0.53), RFD 0-100 (CV=66%; ICC=0.52), RFD 0-200 (CV=17%; ICC=0.72).

3.6 Statistical analysis

Statistical data analysis was completed in IBM SPSS 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). Data was tested for normality using the Shapiro-Wilk normality test. Paired t-tests were used for within-group comparisons to assess pre to post changes in all measurements, and between-group comparisons were made using independent sample t-test (two-group comparison) and one-way ANOVA (three-group comparison). An analysis of covariance (ANCOVA) was used to adjust for any baseline differences between groups. Data are presented as mean ± standard deviation, with 95% confidence interval. The level of significance was set to $p<0.05$. Test-retest reliability was calculated using CV and ICC from consecutive pairwise comparisons, i.e. test 1 versus test 2, as recommended by Hopkins (Hopkins, 2000). Data were graphically presented using the software Prism 8 (San Diego, CA, USA, https://www.graphpad.com).

4.0 Results

4.1 Subject Characteristics

Subject characteristics at baseline are outlined in Table 11, showing no significant baseline differences between training modalities ($p>0.05$). All 49 subjects completed the intervention with the required number of training sessions (minimum 80% attendance).

Table 11. Subject characteristics

Characteristic	Main (n = 49)	Force training (n = 11)	Velocity training (n = 13)	Balanced approach (n = 25)	Individualized approach (n=24)
Age (years)	67.7±5.3	67.8±1.4	67.9±1.2	67±1.2	67.8±4.4
Height (cm)	178.9±7	178.2±2.4	179.7±1.4	178.8±1.6	179±6.4
Weight (kg)	83.4±10.5	79.3±3.4	88.2±2.3	82.6±2.2	84.3±10.7
Total fat mass	22.1±7.	20.1±2.4	24.6±2.3	21.7±1.3	22.5±8.3
Total lean mass	57.9±5.4	56±1.7	60.3±1.1	57.5±1.2	58.5±5.2
Attendance	19.5±1	19.2±1.3	19.9±0.27	19.5±0.89	19.6±0.96

Values are presented as mean ± SD.

4.2 Maximal Power

Following the 10-week training intervention, a significant within-group increase in P_{max} in leg extension was observed with BT (5.5±9.8%, p=0.010), but no significant within-group increase was observed with Force (1.2±6.1%, p=0.525), Velocity (-1.3±6.3%, p=0.358), or IT (-0.2±6.2%, p=0.778) (figure 5A). A significant between-group comparison was observed between BT and Velocity (p=0.028) (figure 5A) and between BT and IT (p=0.019) (figure 5B). No significant group interaction was observed between Force and Velocity (p=0.331), or Force and BT (p=0.186) (figure 5A).

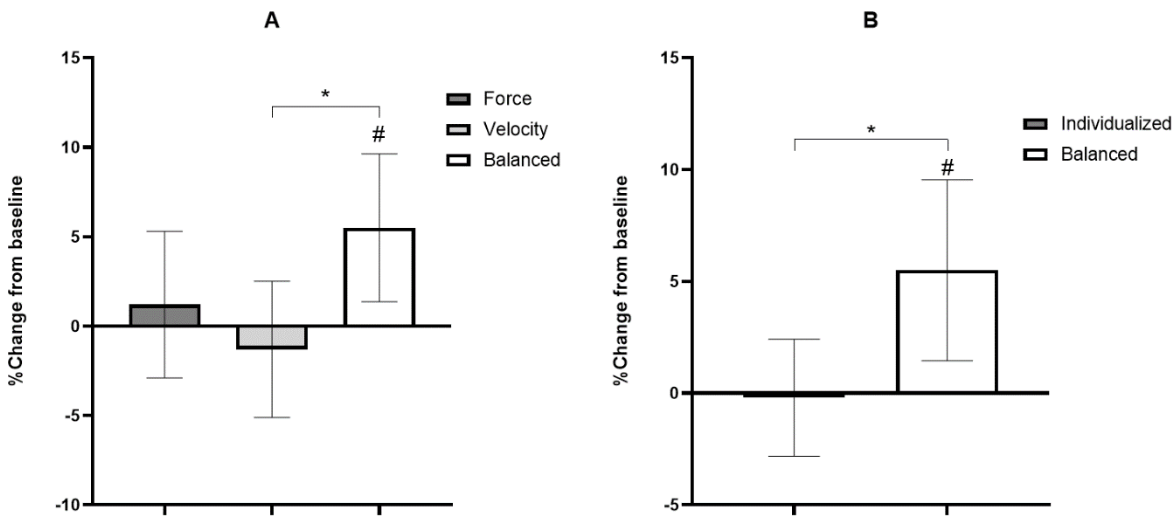

Figure 5 *Percentage change from pre to post in Pmax for A = all groups and B = individualized vs balanced. * significant change between groups, p<0.05; # significant change within group, p<0.05.*

4.3 Rate of Force Development

A significant within-group increase was observed with BT for RFD $peak_{20}$ from pre to post (13±24.5%, p=0.023) (figure 6A), whereas no significant within-group increase was observed with Force (-3.7±9.7%, p=0.171), nor Velocity (5.1±20.3%, p=0.604) (figure 6A). No significant within-group increase was observed with IT in RFD $peak_{20}$ (1.1±16.6%, p=0.925) (figure 6B). A significant between-group comparison was observed between Force and BT (p=0.006) (figure 6A).

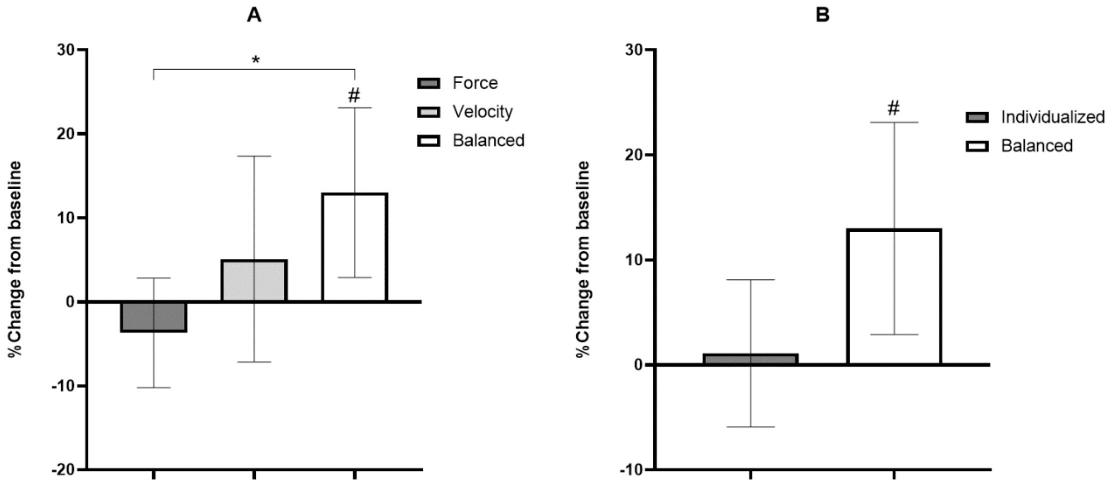

Figure 6 *Percentage change from pre to post in RFD peak$_{20}$ for A = all groups and B = individualized vs balanced.*
** significant change between groups, p<0.05; # significant change within group, p<0.05.*

No significant within-group changes were observed in RFD$_{30}$ in any of the training modalities (Force: 30±69.4%, p=0.423; Velocity: 10±49.9%, p=0.819; BT: 41±65.7%, p=0.096; IT: 19±59.2%, p=0455), and no significant differences between groups (figure 7A). A significant within-group increase was observed with BT for RFD$_{50}$ (40±58.4%, p=0.030), whereas no significant difference was observed for any other training modality (figure 7B). A significant between-group comparison was observed between BT and IT in RFD$_{50}$ (p=0.045) (figure 8B). In RFD$_{100}$ a significant within-group increase was observed with BT (19±30.2%, p=0.006), whereas no other training modality had any significant difference from pre to post (figure 7C). Only BT increased significantly in RFD$_{200}$ (16±24%, p=0.001) (figure 7D). A significant between-group comparison was observed between BT and IT in RFD$_{200}$ (p=0.012) (figure 8D).

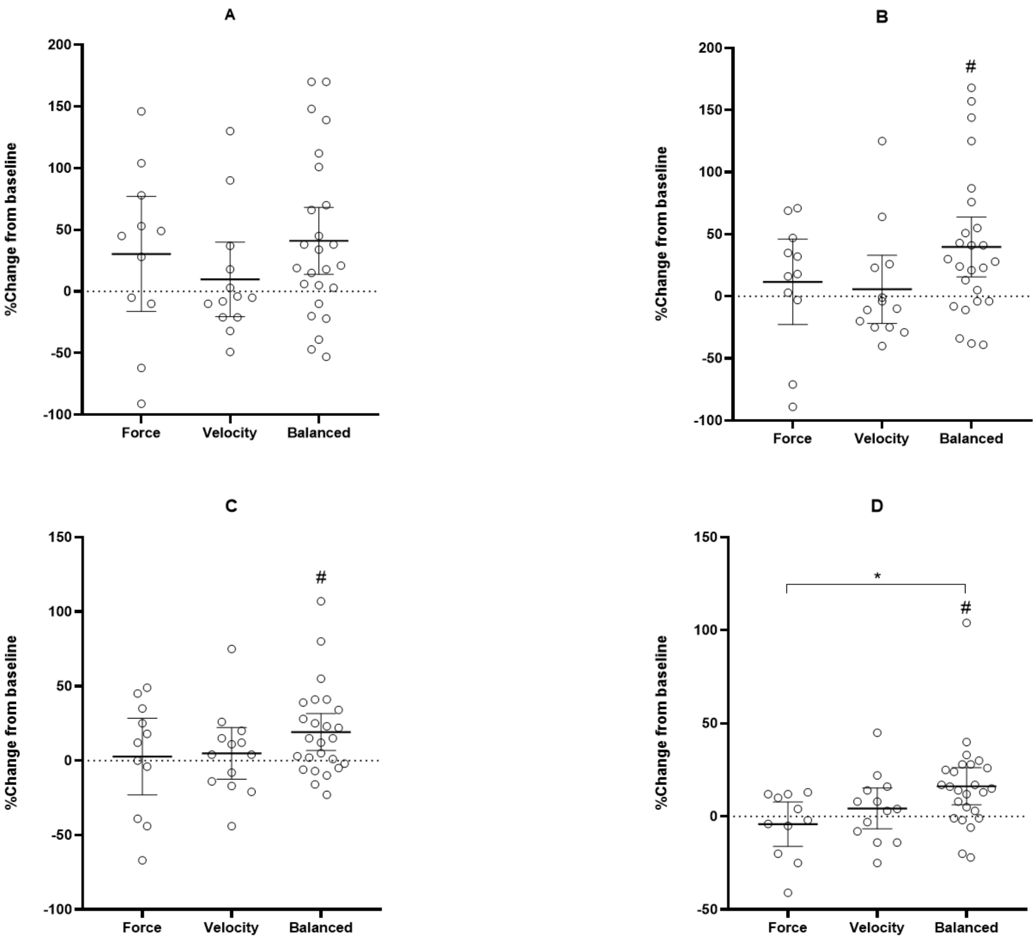

Figure 7 *Percentage changes from pre to post for all groups in A=RFD_{30}, B=RFD_{50}, C=RFD_{100}, and D=RFD_{200}. * significant change between groups, $p<0.05$; # significant change within group, $p<0.05$.*

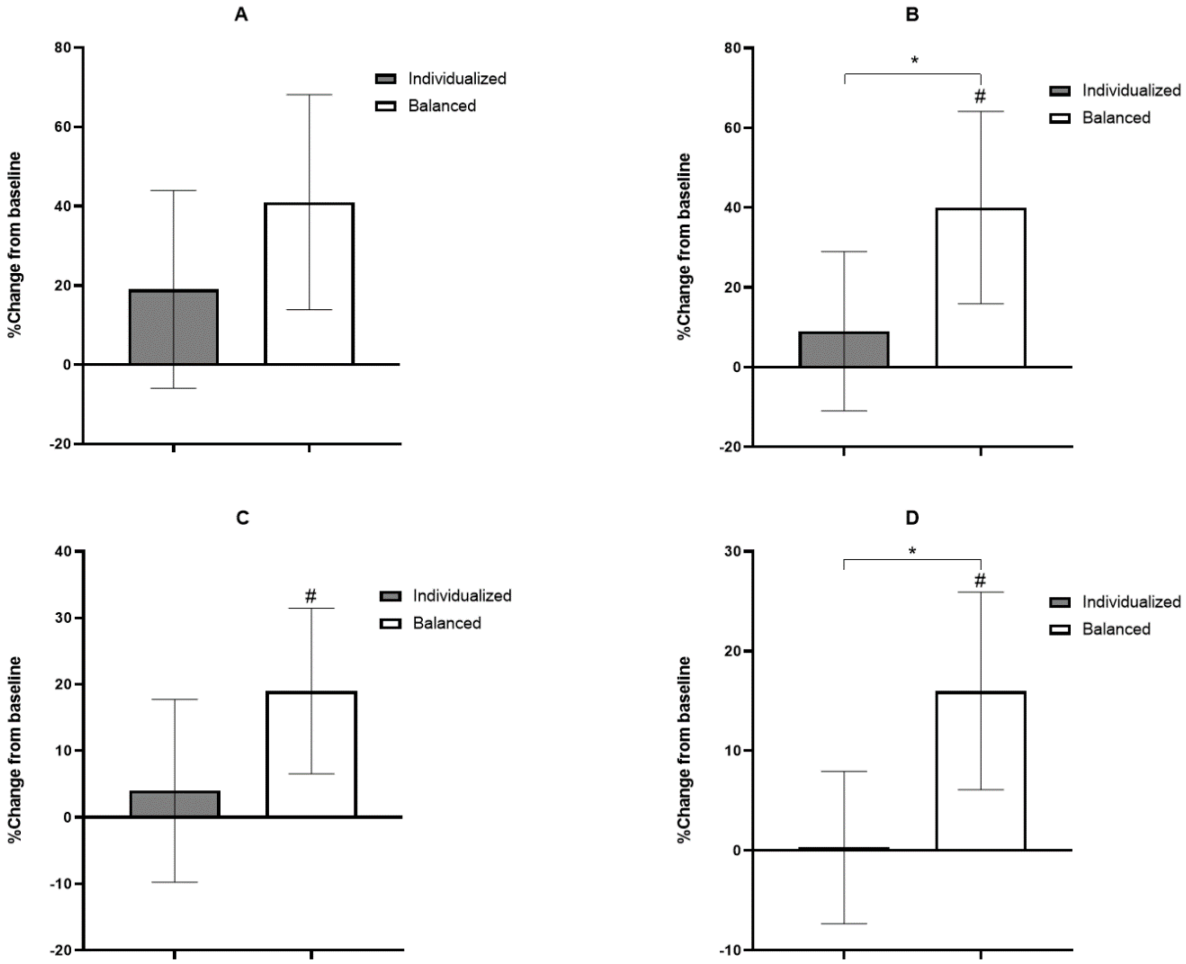

Figure 8 *Percentage changes between individualized and balanced training approach from pre to post in A=RFD_{30}, B=RFD_{50}, C=RFD_{100}, and D=RFD_{200}. * significant change between groups, $p<0.05$; # significant change withing group, $p<0.05$.*

4.4 Myoelectrical Activity

A significant within-group increase was observed in peak EMG *rectus femoris* with Velocity (12.8±14.5%, p=0.013) (figure 9A), and IT (13.3±16.6%, p=0.008) (figure 9B), whereas no significant increase was observed with the other training groups (Force: 14±19.5%, p=0.124; BT: 20.7±45.1%, p=0.058). No significant between-group difference was observed (figure 9A, B). For peak EMG *vastus lateralis,* a significant within-group increase was observed in all training modalities (Force: 20.6±19.4%, p=0.005; Velocity: 14.5±18.2%, p=0.026; BT: 15.7±19.5%, p=0.000; IT: 17.3±18.6%, p=0.000), but no significant difference was observed between groups (figure 10A, B).

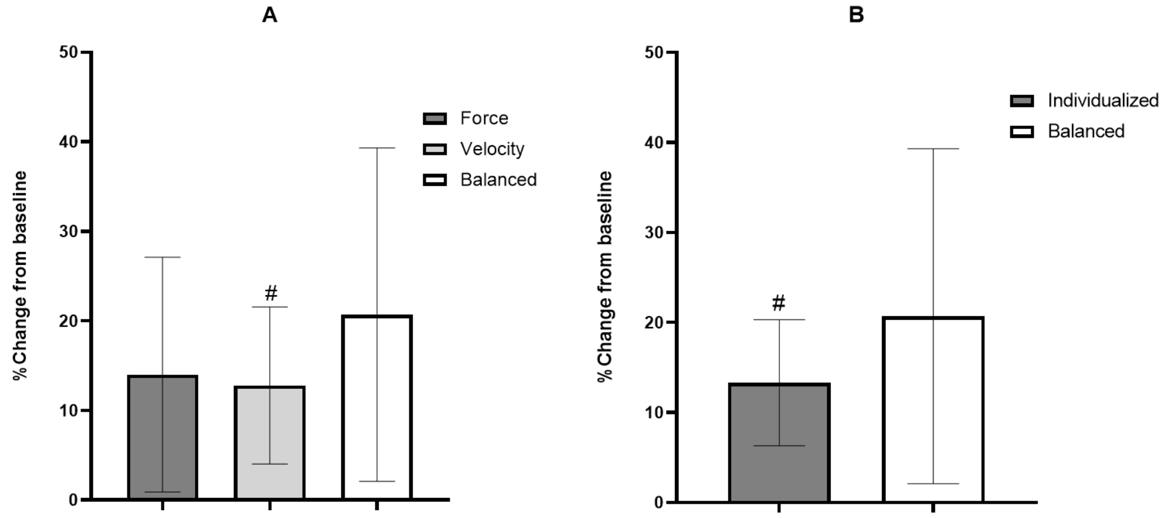

Figure 9 *Percentage change from pre to post in Peak EMG rectus femoris for A = all groups and B = individualized vs balanced. # significant increase within group, p<0.05.*

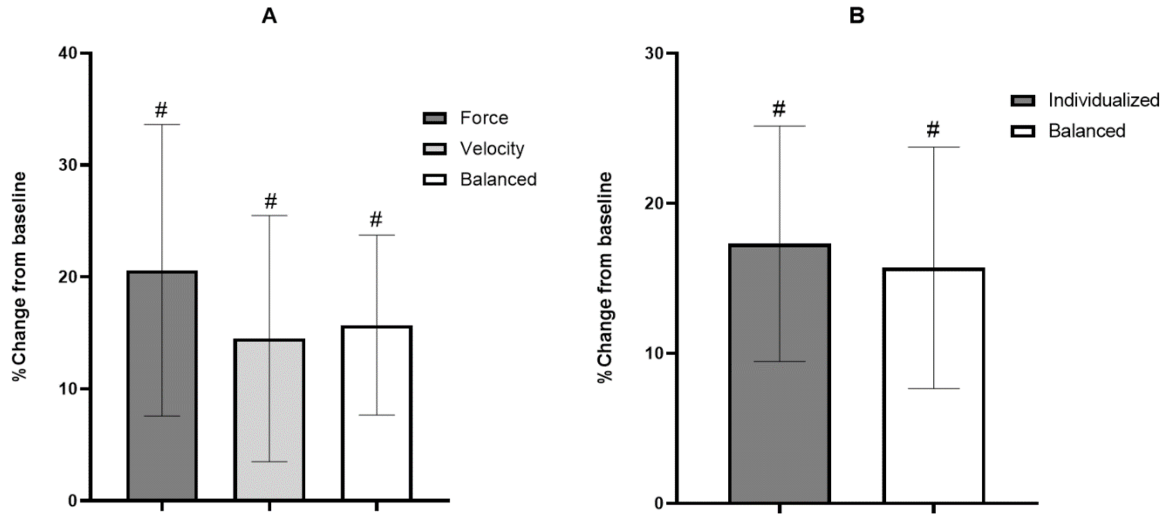

Figure 10 *Percentage change from pre to post in Peak EMG vastus lateralis for A = all groups and B = individualized vs balanced. # significant increase within group, p<0.05.*

4.5 Rate of Myoelectrical Activity

No significant within-group differences were observed in RMA_{30} *rectus femoris* with any of the training modalities (Force: 28±65.3%, p=0.354; Velocity: 29±59.3%, p=0.362; BT: 23±57.2%, p=0.665; IT: 28±60.7%, p=0.180) (figure 11A, 8A). No significant changes were observed in RMA_{50} *rectus femoris* with any of the training modalities (Force: 31±77.8%, p=0.263; Velocity: 27±64.7%, p=0.406; BT: 28±50.8%, p=0.166; IT: 29±69.4%, p=0.152) (figure 11B, 8B). No significant differences were observed in RMA_{100} *rectus femoris* with any of the groups (Force: 23±60.1%, p=0.276; Velocity: 21±38.1%, p=0.095; BT: 27±55.3%, p=0.137; IT: 21±48.2%, p=0.052) (figure 11C, 8C). No significant within-group difference were observed in RMA_{200} *rectus femoris* with Force (22±44.4%, p=0.092), whereas a significant within-group difference were observed in the remaining training groups (Velocity: 23±17.1%, p=0.000; BT: 19±37.5%, p=0.035; IT: 23±31.8%, p=0.000) (Fig 11D, 12D). No significant between-group differences were detected in any of the four RMA intervals.

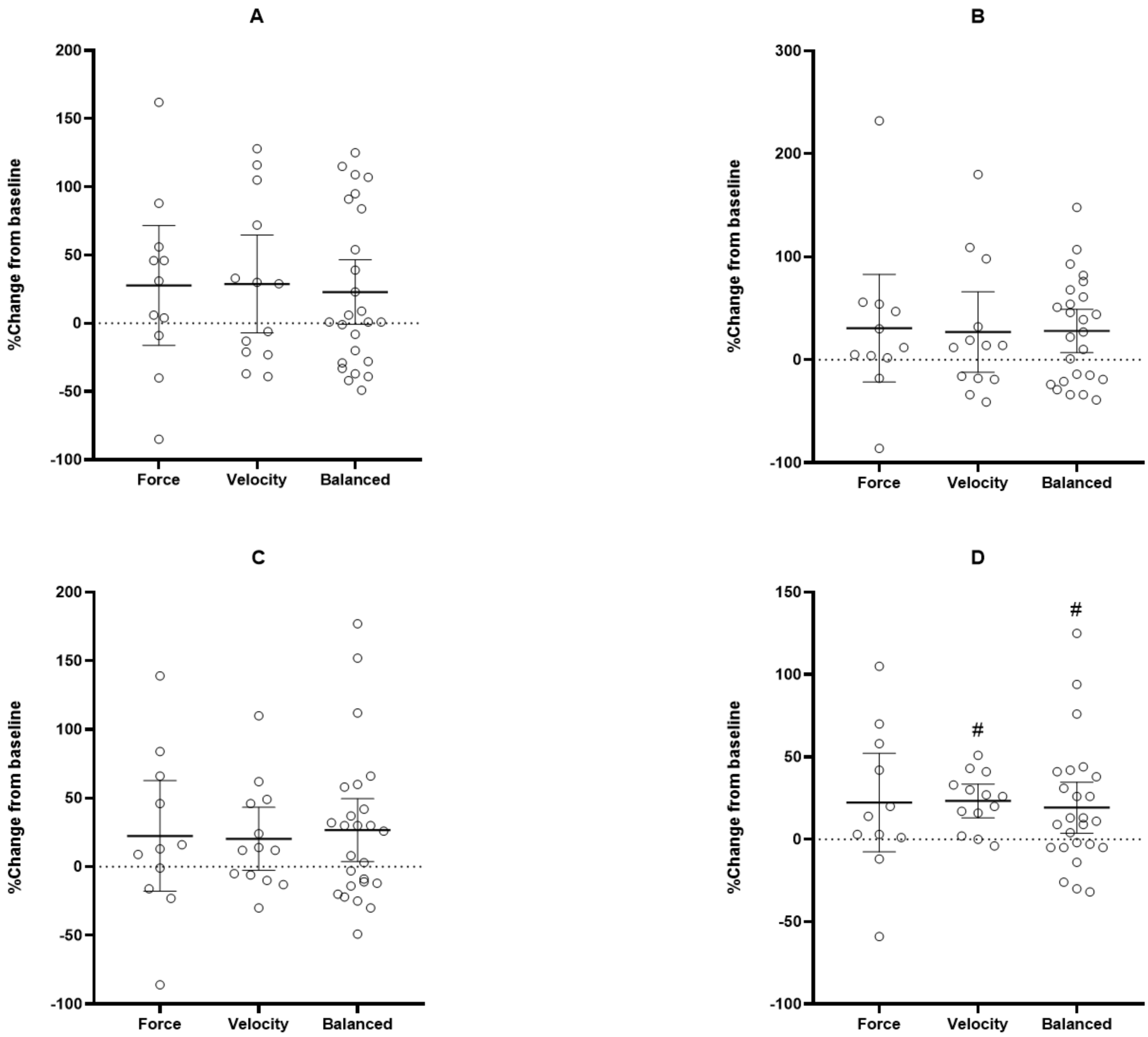

Figure 11 *Percentage changes from pre to post for all groups in A=RMA_{30}, B=RMA_{50},* C=RMA_{100}, D=RMA_{200} *rectus femoris. # significant increase within group, p<0.05.*

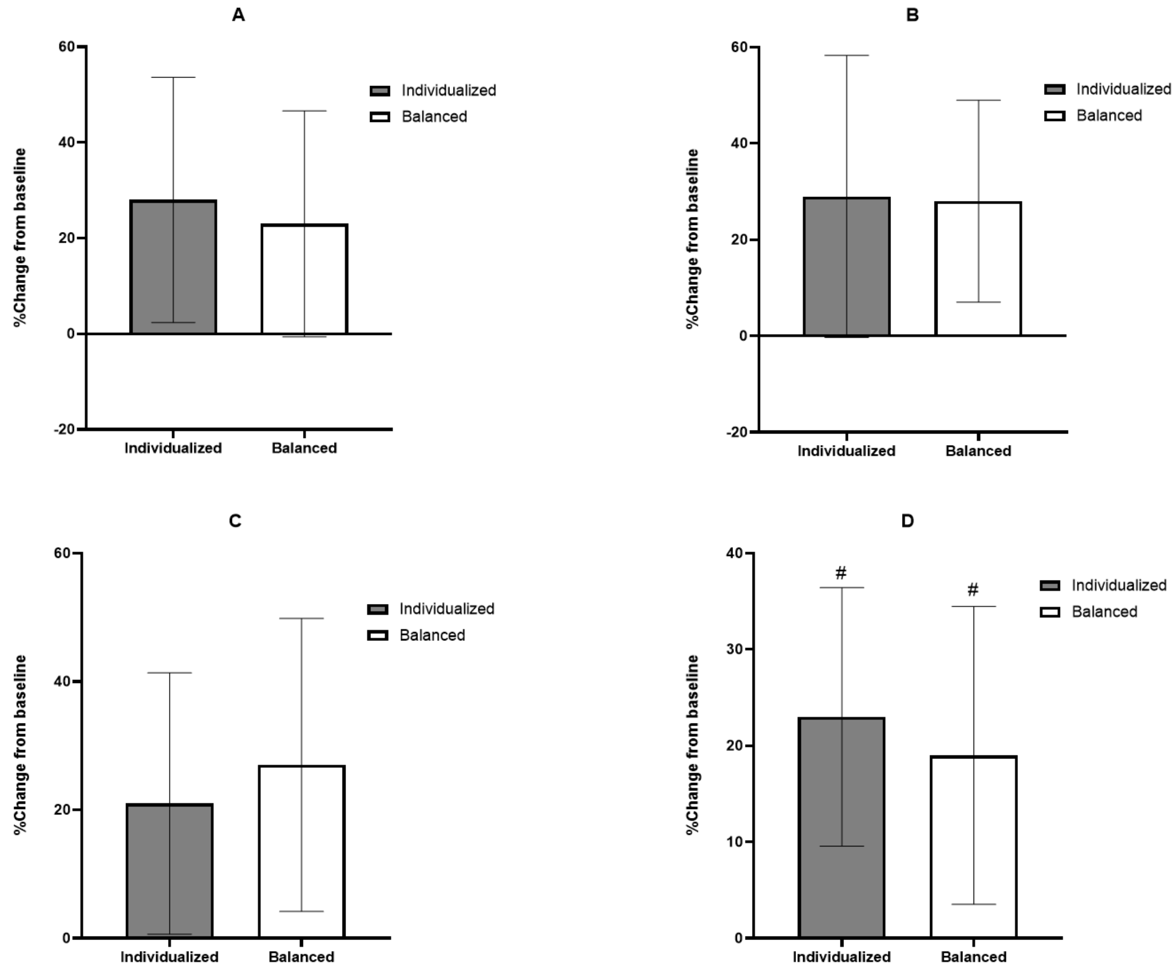

Figure 12 *Percentage change in A=RMA_{30}, B=RMA_{50},* C=RMA_{100}, D=RMA_{200} *rectus femoris individualized vs balanced. # significant increase within group, p<0.05.*

No significant within-group increases were observed with any of the training groups in RMA_{30} *vastus lateralis* (Force: 54±114.5%, p=0.348; Velocity: 9±52.4%, p=0.756; BT: 49±145.7%, p=0.422; IT: 29±87.6%, p=0.497) (figure 13A, 14A). No significant differences were observed with any of the training groups in RMA_{50} *vastus lateralis* (Force: 49±74.3%, p=0.124; Velocity: 21±47.1%, p=0.546; BT: 38±96.4%, p=0.320; IT: 34±61.4%, p=0.103) (figure 13B, 14B). A significant within-group increase was observed in RMA_{100} *vastus lateralis* with IT (31±43.5%, p=0.015), but not in the remaining training modalities with (Force: 36±50.4%, p=0.097; Velocity: 26±38.3%, p=0.079; BT: 20±47.7%, p=0.222) (figure 13C, 14C). A significant difference were observed within all training groups in RMA_{200} *vastus lateralis* (Force: 31±30%, p=0.008; Velocity: 27±32.9%, p=0.026; BT: 22±31.3%, p=0.010; IT: 29±31%, p=0.000) (figure 13D, 14D). No significant between-group differences detected in RMA_{200} *vastus lateralis*.

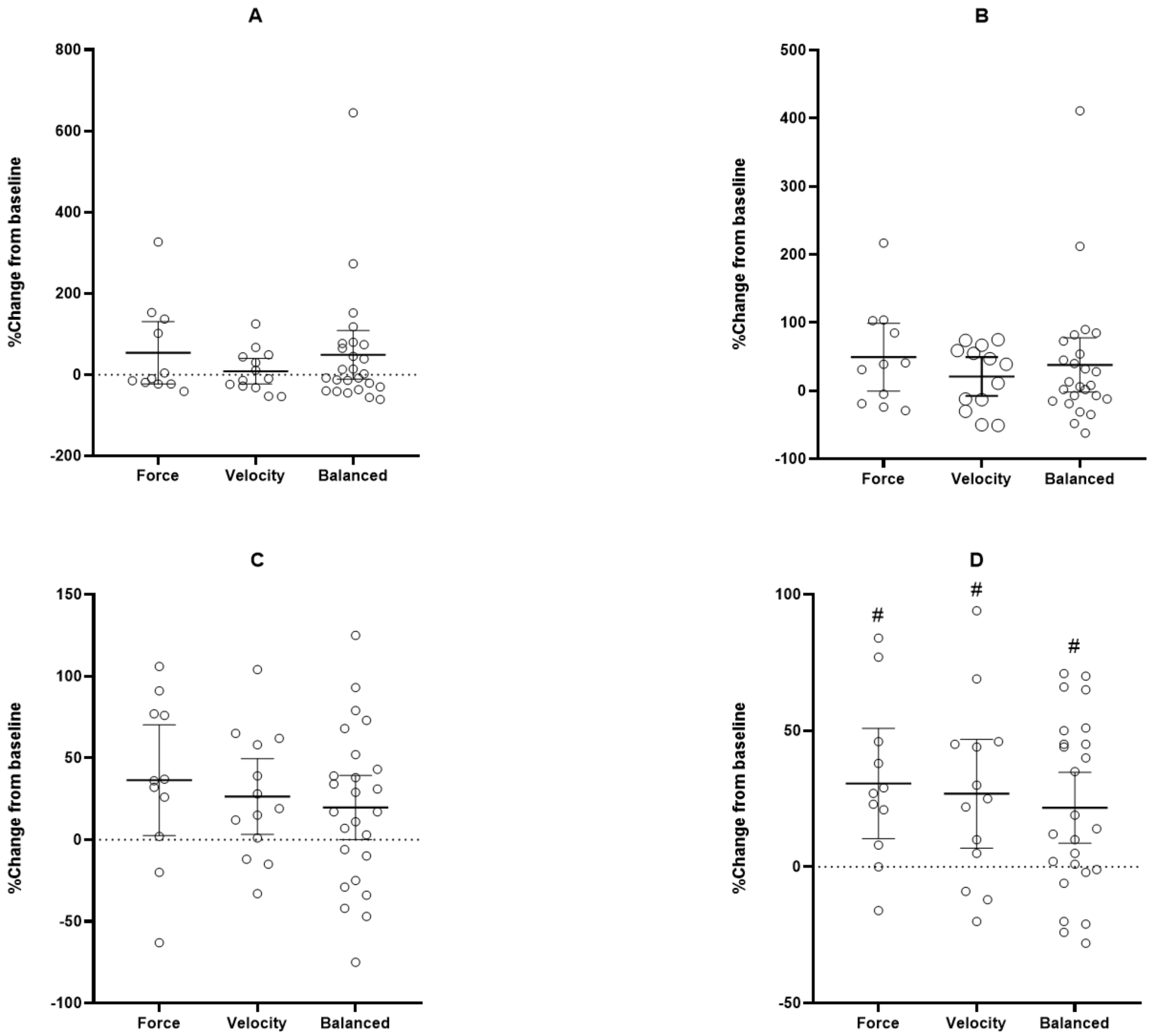

Figure 13 *Percentage changes from pre to post for all groups in A=RMA*$_{30}$*, B=RMA*$_{50}$, C=RMA$_{100}$, D=RMA$_{200}$ *vastus lateralis. # significant increase within group,* $p<0.05$.

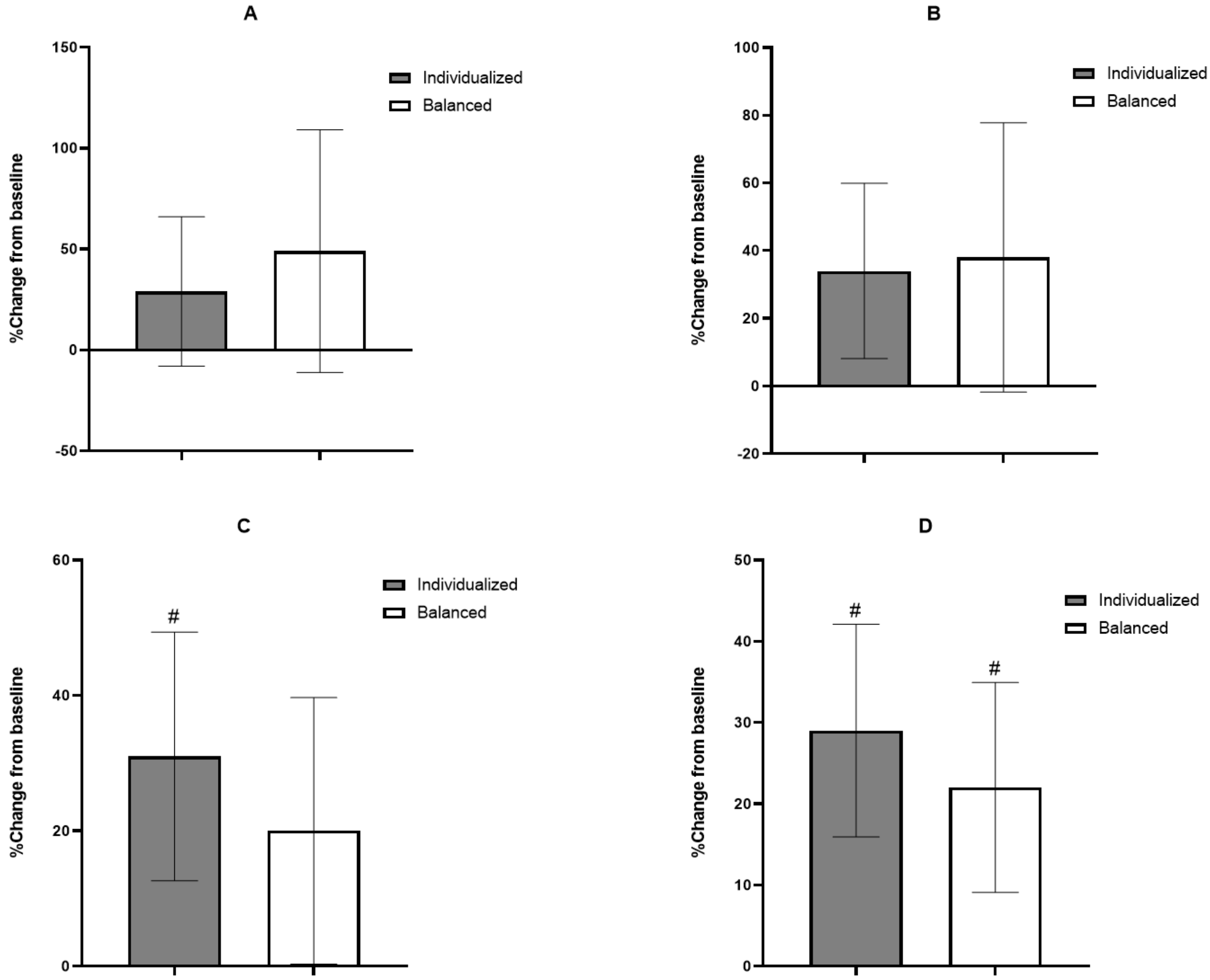

Figure 14 *Percentage change in A=RMA*$_{30}$, *B=RMA*$_{50}$, C=RMA$_{100}$, D=RMA$_{200}$ *vastus lateralis individualized vs balanced. # significant increase within group, $p<0.05$.*

5.0 Methodological discussion

5.1 Study design

The present study was conducted as a randomized controlled trial. According to literature, randomized controlled trials (RCT) is the most systematic and reliable method of study to assess whether a cause-effect relationship exists between an intervention and an outcome (Bhide, Shah & Acharya, 2018). Randomization reduces bias and balances subject characteristics (both known and unknown confounding factors) between groups, this produces high internal validity and allows for any variations in result to be attributed to the research intervention (Hariton & Locascio, 2018). RCTs are therefore considered the "gold standard" and regarded as one of the most valued research methodologies for investigating the effectiveness of an intervention (Houle, 2015). However, RCTs are not without flaws, one of the major drawbacks in this kind of study design is the problem with generalizability. Subjects who volunteer may not always be representative of the population being studied (Hariton & Locascio, 2018). Some subjects displayed high measurements during testing which may cause a *ceiling effect*, making it difficult to accurately measure that person's true scores since the independent variable no longer has an effect on the dependent variable (Salkind, 2010). Another drawback to RCTs concerns the Hawthorne effect. Subjects awareness of being studied may possibly impact behavior (McCambridge, Witton & Elbourne, 2014), thus, obscuring the effect of research variables (Polit & Beck, 2017).

5.2 Study sample

49 (n=49) home-dwelling male subjects, aged >60 years old participated in the present study. Originally, there were 56 total subjects included, however, seven (n=7) subjects had to dropout due to various reasons. According to the power analysis performed prior to the recruitment period, target sample was 65 subjects (25 in each intervention group), including 15 subjects in a non-training control group. However, since subject participation did not meet the initial target sample size, the control group had to be removed, limiting the study to a certain degree. First and foremost, there is a higher possibility of making a type II error since a sample size smaller than the ideal increases the chance of making an erroneous acceptance of false null hypothesis (H_0) (Faber & Fonseca, 2014). Furthermore, having a non-training control group allows for an examination of what changes were *caused* by the intervention because only some subjects were exposed to it (Polit & Beck, 2017). Therefore, the termination of the control group places a limitation on the study since it provides an important

comparison (Polit & Beck, 2017). In addition, the subjects (and investigators) had knowledge of which training group subjects were assigned to, making the study non-blinded. The purpose of conducting an RCT is to eliminate bias, such as unconscious information bias by blinding the subjects (single-blind) or both subjects and investigators (double-blind) (Bhide et al., 2018). However, it was not possible to blind subjects or investigators due to the nature of the study. It was unrealistic to request training personnel from the outside and subjects were informed of the differences separating the two training interventions.

5.3 Training Intervention

The training intervention period was initially 12 weeks but was shortened to 10 weeks due to time restraints. Previous research has suggested that training periods between 10 to 56 weeks for high-intensity training programs (>75% of 1RM) are sufficient for increasing skeletal muscle strength and power outputs in adults over 65 years old (Marcos-Pardo et al., 2019). Thus, a 10-week training intervention appear adequate for producing improvements in all measurements. Regarding training frequency, in the present study subjects trained two times per week for the whole training period. In a position stand on resistance training in healthy adults from the American College of Sports Medicine, a frequency of 2 to 3 days per week was recommended for power training novices (MSSE, 2009). Similar recommendations were outlined in a position statement on resistance training for older adults from the National Strength and Conditioning Association (Fragala et al., 2019). Therefore, since subjects were both novice in terms of resistance training and of the older population, a training frequency of 2 days per week seem fair. Training load differentiated between each training program: training load for velocity varied between -20% (overload) and 50% of 1RM, force training was set at 80% of 1RM, whereas the balanced training approach combined the two. The literature suggests similar loads for increasing muscle power (heavy/force: >80% of 1RM, light/velocity: 30-60% of 1RM) (McArdle et al., 2015). Overload plyometric training (assisted using elastic equipment) has shown to be an effective method for producing a rapid increase in muscle power in both young and older individuals (Franchi et al., 2019). When estimating training load for balanced and force training groups, the repetitions in reserve (RIR) method was used. RIR may be an appropriate method for estimating training load for power training with the goal of developing the high-force end of the power spectrum (>80% 1RM) (Helms et al., 2016). However, it is most likely not possible to determine actual RIR for low intensity high-velocity power training (Helms et al., 2016), thus RIR was reserved for balanced and force training groups only in the present study. Before each training session, subjects had to perform an active warm-up protocol consisting of light jogging up a flight of stairs, as well as a task-specific warm-up as an additional set in each training exercise. Active warm-up tends to result in slightly better improvements in short-term performance (<10 seconds) and the addition of a task-specific warm-up should provide further ergogenic benefits for most tasks (Bishop, 2003).

5.4 Measurements

Collection of data is necessary in order to examine the effects of an exercise intervention. A pretest-posttest design was, therefore, necessary in order to achieve this. However, in order to determine the feasibility of the testing protocol, a pilot test was conducted prior to beginning the study. Pilot tests have shown to be necessary and useful in providing the groundwork in a research project (Hassan, Schattner & Mazza, 2006). One of the most important issues regarding measurements of research variables is data quality, i.e. validity (the degree to which a test or instrument measures what it is supposed to measure) and reliability (how repeatable or consistent a measurement is) (Thomas, Nelson & Silverman, 2015). In order to increase measuring reliability, subjects had to complete two sessions of testing (for pre- and post-testing) as well as one familiarization testing in order to eliminate any potential learning effect. Regarding validity, standardized protocols conducted in previous research were followed, in addition, tests were always supervised by the same test leader each time.

5.4.1 Dual-energy X-ray Absorptiometry

Measurements of subject body composition was performed using the Dual-energy X-ray absorptiometry (DXA). DXA is for the most part the preferred method for measuring bone and body composition (Shepherd, Sommer & Heymsfield, 2017) since it guarantees a precise assessment of the three main body components (i.e. bone mineral content, non-bone lean mass, and fat mass) (Ponti, Plazzi, Guglielmi, Marchesini & Bazzocchi, 2019). Furthermore, DXA is reported to be a reliable method for assessing skeletal muscle mass in in healthy men and women (Kim, Wang, Heymsfield, Baumgartner & Gallagher, 2002). There are other accurate methods for assessing skeletal muscle mass, such as computed axial tomography (CT) and magnetic resonance imaging (MRI), however, such methods are costly and limited (Kim et al., 2002). Thus, a DXA instrument offered an alternative and relatively inexpensive method for measuring body composition.

5.4.2 Leg press power test

Subject randomization to different training groups were based on subjects' slope in their force-velocity profiles. In order to do this a seated leg press protocol in the Keiser Pneumatic Leg-Press was used. Measurement of lower limb strength and power in this protocol has been reported to be a valid and reliable method (Redden et al., 2018). The test-retest reliability examined between pre-test 1 and 2 showed a coefficient of variation (CV) value of 9.6%, which can be considered less reliable than previously reported in other studies where a CV value ranging between 1.8 to 6% is considered "excellent" (Redden, 2019). Intraclass correlation coefficient (ICC) between pre-test 1 and 2 showed a value of 0.81, which is also lower than previously reported in the same protocol where a value of >0.92 is considered excellent (Redden, 2019). It is worth noting that these results are collected from professionally trained athletes and not older adults, in addition an unexpected movement technique may influence results, therefore, the need for extensive familiarization is important for removing any potential learning effect (Redden, 2019). Including an extra familiarization session may prove useful.

5.4.3 Leg extension power test

The test protocol for power assessment in leg extension consisted of an incremental load method. To our knowledge, the exact same protocol is not described anywhere else. However, a similar incremental load protocol in full-squat and bench press exercises has been described elsewhere (Pallarés et al., 2013), as well as a method for power assessment in the leg extension machine (load: 40% and 70% 1RM, isokinetic 90˚) (Callahan et al., 2007). The test-retest reliability between pre-test 1 and 2 showed a CV value of 4% and an ICC value of 0.91, which can be considered excellent when, previously reported values of CV=9.5%, 4.0%, 5,9%, ICC=0.80, 0.95, 0.90 (Sheppard, Cormack, Taylor, McGuigan & Newton, 2013) and ICC=0.80, 0.78, 0.84 (Callahan et al., 2007) in similar protocols are considered high/excellent.

5.4.4 Electromyography

EMG is an established evaluation tool for measuring myoelectric activity (Konrad, 2006) and was, therefore, conducted in order to directly measure subjects motor unit firing of *vastus* *lateralis* and *rectus femoris* muscles in both legs. Single-joint activities held statically at middle positions within the range of motion typically gives the best results (Konrad, 2006). Thus, an isometric maximum voluntary contraction method was conducted. Similar test protocols can be described elsewhere (Alkner et al., 1999; Trajano, Seitz, Nosaka & Blazevich, 2019; Balshaw, Fry, Maden-Wilkinson, Kong & Folland, 2017). The test-retest reliability was measured between pre-test 1 and 2 and showed relatively high CV values (ranging from 15% to 39%) and low ICC values (ranging from 0.35 to 0.75) for all measurements, which can be considered less than good compared with results reported in previous studies (Fauth et al., 2010; Trajano et al., 2019). One of the major limitations in the EMG measurement is the problem of physiological "cross talk" (Konrad, 2006). Electrode placement sites were to be marked for each subject during ultrasound, however, this was not always done. The consequences of this can be problematic since neighboring muscles may produce a significant amount of EMG that is detected by the electrode. Although it typically does not exceed more than 10% to 15% of the overall signal, it may still interfere with the EMG recording (Konrad, 2006). Furthermore, results from a previous study suggest that proper surface electrode placement should follow the orientation of the muscle fiber (Ahamed et al., 2014).

5.4.5 Rate of Force Development

Rate of force development (RFD) was measured simultaneously as EMG during an isometric maximum voluntary contraction protocol consisting of three trials per leg. Peak RFD was determined from a moving sampling window of 20ms, which has been recommended in previous research (Rodriguez-Rosell et al., 2018). Time-intervals of 0-30ms, 0-50ms, 0-100ms and 0-200ms was selected for measuring time-interval RFD. Similar time-intervals have been described elsewhere (Haff et al., 2015). Test-retest reliability between pre-test 1 and 2 showed high CV (ranging from 66% to 88%) and low ICC values (ranging from 0.42 to 0.53) for all time-intervals except RFD 0-200 (CV=17%; ICC=0.72) and RFD $peak_{20}$ (CV=13%; ICC=0.82). The reliability for RFD $peak_{20}$ may be considered good since a previous study reported that a CV value of 12.9% for RFD $peak_{20}$ met the reliability criteria (Haff et al., 2015). Although the reliability of RFD has consistently been found to be lower during the early phases of muscle contraction, the values found in the present study are still far from ideal. A study investigating RFD in an isometric mid-thigh pull test reported values of CV=15%, ICC=0.86 (0-50ms), CV=13%, ICC=0.85 (0-100ms), CV=8%, ICC 0.93 (0-

200ms) (Suarez et al., 2019). Another study reported CV values of 12.8-16.6% for a 0-50ms time window to be less than ideal (Maffiuletti et al., 2016).

5.5 Main strengths and weaknesses

The main strengths of the present study were: (a) a solid study design, (b) a well thought-out and extensive test-protocol, (c) two pre- and post-tests with the same measurement instruments and test leaders for each test, (d) close control of adherence during training, as well as high attendance each training sessions.

Whether or not the subjects themselves were representative of the population being studied is difficult to confirm since some of them were already in relatively good physical condition. One of the main limitations to the present study can be found in the reliability of some test measurements, mainly EMG and RFD. Poor reliability produces imprecise reflections of subjects' true ability and have a fundamental impact on the results and the way they are interpreted. Furthermore, the small within-groups sample size can lead to type II errors. The lack of a control group further limits the study.

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RESEARCH PAPER

Traditional- vs individualized training based on force-velocity profiling on power and neuromuscular adaptations in older men

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Traditional- vs individualized training based on force-velocity profiling on power and neuromuscular adaptations in older men

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ABSTRACT

INTRODUCTION. Muscle power is reportedly a good indicator of functional independency in elderly. Individualized power-training based on force-velocity (F-v) profiling has received increasing attention for optimizing muscle power development. This study aims to investigate effectiveness of individualized power-training program based on F-v profiling on maximal power (P_{max}), rate of force development (RFD), myoelectric activity (EMG), and rate of myoelectric activity (RMA) in older men.

METHOD. Forty-nine older men underwent physical testing before and after a 10-week training intervention. Subjects randomized to individualized (IT) or balanced power training groups (BT) based on F-v profiling. F-v profiles were obtained from Keiser leg-press. RFD, EMG, and RMA data were collected under an isometric maximum voluntary contraction in leg extension. Muscle power measured with incremental loads in leg extension.

RESULTS. Within-group increases only with BT in P_{max} (p=0.010), peak RFD_{20} (p=0.023), RFD_{50} (p=0.030), RFD_{100} (p=0.006), and RFD_{200} (p=0.001). No within-group differences in RFD_{30}. Between-group difference only in P_{max}, RFD_{50}, and RFD_{200} between BT and IT (p=0.019; p=0.045; p=0.012, respectively). Within-group differences for all groups in peak EMG *vastus lateralis*, while only IT increased in peak EMG *rectus femoris*. Within-group difference with BT and IT in RMA_{200} *rectus femoris* and *vastus lateralis*. Within-group difference only with IT in RMA_{100} *vastus lateralis*. No differences in the other RMA intervals.

CONCLUSION. Results indicate balanced power training more beneficial for improving P_{max} and RFD in older men, with no difference in EMG. Use caution when recommending an individualized training approach based on F-v profiling in older men.

KEYWORDS. Power training, force-velocity profile, maximal power, rate of force development, myoelectric activity, rate of myoelectric activity, older men

1 | INTRODUCTION

Physical functioning tends to decline as we get older, thus increasing incidence of disabilities related to walking and movement[1]. Progressive loss of muscle strength, due to atrophy of muscle mass occurs naturally with advancing age[2]. Decrease in muscle mass is about 1 to 2% annually by the 5th decade of life and declines in muscle strength is suggested to be about 1.5% per year after aged 60[3]. In addition, muscle power has been shown to decrease about 3 to 4% faster than muscle strength and should be of concern since muscle power better explains variance in physical functioning in older adults than muscle strength alone[4]. This decline in muscle power in older adults heightens the risk potential for accidents due to muscle weakness, fatigue, or poor balance[5].

Age-related reductions in skeletal muscle strength and power is not only limited to changes in skeletal muscle systems but can also be attributed to changes in the nervous systems[6]. Skeletal muscles work under voluntary control, meaning they will contract or relax when they receive electrical signals[7]. *Myos* is latin for muscle[8], therefore, electrical activity from the nervous system that activates muscles (myos) is termed myoelectric activity[9]. Skeletal muscle fibers are controlled by alpha motor neurons in the anterior horns of the spinal cord and in motor nuclei of the origin of the cranial nerves[7]. A motor unit is the neuron and the specific muscle fibers that it innervates[7]. Motor units are recruited according to the size principle, meaning relatively small alpha-motoneurons innervating type I fibers are initially triggered at low force levels, whereas increasingly larger alpha-motoneurons that trigger type IIa and IIx fibers usually activates at higher force thresholds[10]. Production of muscle power becomes greater with increasing signal frequency due to a stepwise increase in firing rate of motor units[11]. Firing frequency of motor units (rate of myoelectric activity) is the rate of neural impulses transmitted from alpha-motoneurons to the muscle fibers[10]. Moreover, rate of myoelectric activity also affects rate of force development (RFD) of muscle contraction[10]. RFD reflects the rate at which muscle tension can be developed and is important in movements that require rapid action such as sprinting, jumping, or reversing a fall[12]. RFD is shown to enhances the quality of life in elderly[13], for instance, an elderly person can decrease risk of falling by being able to exert a rapid increase in muscle force[14].

When a muscle is activated, an electrical discharge (myoelectric signal) is produced, which can be measured directly via electrodes[15]. These myoelectric signals yield information about the intensity and duration of a muscle contraction[15]. Myoelectric activity is normally measured during voluntary muscle actions by placing surface electrodes close to the muscle of interest[9]. The measured signal reflects the summation of all activated motor units within the electrode area[15].

There are currently no standardized resistance training guidelines for improving muscle strength and power among older adults[6]. However, research has provided strong evidence that resistance training for elderly can help mitigate losses of neuromuscular function and functional capacity, notably with the inclusion of power training exercise[16]. Power training is characterized by performing traditional resistance training exercises at the highest possible velocity during the concentric phase of the lift and spending approximately 2 to 3 seconds on the eccentric phase[17]. Power training has shown to be more effective at improving performances in functional tasks compared with a traditional approach[16].

Since power is the product of force multiplied by velocity, these two components underpin the ability to be powerful, moreover, it is possible for two individuals to display resembling power output even if their force and velocity capacities differ[18]. This force-velocity (F-v) relationship is a representation of the inverse relationship between force and velocity[10], meaning, as the velocity of a concentric muscle movement increases, the force produced will simultaneously decrease[11]. Maximal power will therefore occur at an optimal combination of submaximal force and velocity values[10]. Theoretically, individuals are skewed toward either strength (force) or speed (velocity), which can hinder them in explosive movements. Determining whether an individual is force- or velocity-deficient may be advantageous[19].

A force-velocity profile (F-v profile) shows the proportion between an individual's maximal force and velocity capabilities and can be determined by the slope of the F-v relationship[18]. An ideal/optimal F-v profile exists for every individual, representing the best balance between their force and velocity capacities[18]. Jiménez-Reyes et al.[19] investigated the effects of an individualized resistance training based of F-v profiling in trained athletes and suggests that targeted resistance training based on individual F-v profiling is an effective way to improve jumping performance in trained athletes. Since jumping performance is highly influenced by the ability to produce muscle power in a short time frame[10], similar findings may emerge in an older population. Therefore, the aim of this 10-week randomized controlled trial was to investigate which training approach (traditional strength training or individualized power training based on F-v profiling) is more effective to improving maximal power, rate of force development, myoelectric activity, and rate of myoelectric activity in elderly men.

2 | MATERIALS AND METHODS

2.1 | Subjects and study design overview

Forty-nine healthy home-dwelling adult males (age = 67.7±5.3 years, body mass = 83.4±10.5kg, stature = 178.9 ± 7cm) volunteered to participate in this study, which was approved by the Norwegian Centre for Research Data (NSD) (reference nr. 923574). Permission to conduct the study was granted by the local ethics committee for the Faculty of Health and Sport Science at the University of Agder and has been operated in accordance with the Declaration of Helsinki. Subjects had to be aged >60 years old and provide a written medical clearance from their personal physician in order to be included. Subjects were excluded if they had any illnesses or injuries preventing them from safely participating in heavy resistance training, and if they had participated in systematic strength training six months prior to the study. Participation was voluntary and subjects could at any moment withdraw, without stating any reason. Written consent was obtained from all subjects.

Prior to starting training intervention, each subject had to complete one week of familiarization testing, and two weeks of baseline testing in order to minimize any potential learning effect. Subjects were stratified randomized into either a balanced training group (BT) or an individualized training group (IT) based on their F-v profile in Keiser leg-press. Subjects were rated based on their mean slope in Keiser leg-press, with the upper half considered as force dominant and the lower half as velocity dominant. Subjects were then randomized into either the BT group (n=25) or the IT group (n=24) using a random number generator. IT training group received a power training program dependent on their F-v profiles, meaning they would train on their deficit. A subject considered force dominant (n=13) would train velocity, and a velocity dominant subject would train force (n=11), these would become sub-groups of IT. BT group received a comparable power training program independent of their F-v profile, meaning a more traditional approach combining force and velocity.

The training intervention lasted for 10 weeks with two training sessions per week, for a total of 20 sessions. Estimation of load occurred after baseline testing, and prior to the training period. Training load was adjusted properly in the first week of training during familiarization using the repetitions in reserve method (RIR)[20]. After five weeks of training, the load was adjusted once more using the same method to accommodate for adaptation.

Subjects trained with close control of adherence in order to ensure their safety, provide guidance, and motivate them. Therefore, a minimum of one training instructor was always present during training. After the intervention, subjects had to complete two rounds of post-testing with a week of rest in-between. Both subjects and investigators had knowledge of which training group they belonged to, making it non-blinded.

2.2 | Training intervention

Training period lasted for 10 weeks, and subjects had to attend two sessions per week, for a total of 20 sessions. Subject participation was recorded for each session, and subjects could be absent from training four times in total. If exceeded, the subject was excluded from the study. Training programs were split into two separate days, one for each session, customized with their own sets of exercises based on training groups. Velocity dominant subjects in the IT group trained with a focus on heavy lifting with an intensity of 70-80% of 1 repetition maximum (1RM), and 6-8 repetitions.

2.2 | Test procedure and measurements

The test protocol consisted of a fasted dual-energy X-ray absorptiometry, unilateral leg-press power test, leg extension power test, and electromyography (EMG) and RFD measurements in leg extension. Leg-press power test is presented due to its role in the stratified randomization of subjects in this study. Force dominant subjects in the IT group trained with a focus on velocity with a lower intensity, usually 20-50% of 1RM, and 5 repetitions. BT combined force training and velocity training with no individual specificity, with one session dedicated to heavy lifting, and the other to velocity. All subjects were instructed to perform each repetition as explosively as possible, meaning high velocity during the concentric movement of the lift. After five weeks of training, the load was adjusted once more using RIR to accommodate for adaptation. However, subjects training velocity did not increase training load during this time. Instead, training personnel measured velocity using a linear encoder connected to a laptop with dedicated software (MuscleLab; Ergotest, Langesund, Norway). This way, subjects were motivated to increase their velocity with each repetition performed. Subjects trained with close control of adherence in order to ensure their safety, provide guidance, and motivate them. Therefore, a minimum of one training instructor was always present during training.

2.2.1 | Dual-energy X-ray absorptiometry

Body composition was measured by dual-energy X-ray absorptiometry using a Lunar Prodigy (model 8743; GE Lunar Corporation, Madison, WI, USA). Subjects had to perform body assessment in a fasted state. Height and weight for each subject was recorded before the test, and bodily ornaments such as jewelry and watches were removed. Subjects were scanned from head-to-toe in a supine position, measuring fat and lean muscle mass in arms, legs, and trunk.

2.2.2 | Leg-press power test

To complete F-v profiling, Keiser Pneumatic Leg-Press was used (Keiser Sports Health Equipment Inc., Fresno, CA, USA). Knee angle was set to approximately 90˚ for all subjects using a Baseline 14-inch Stainless Steel 360 Degree Goniometer. During familiarization, testing procedure consisted of a six repetitions power test in a seated position with feet flat on each foot plate. The test consisted of five different incremental loads, with two attempts per load. Subjects were instructed to "push as hard and fast as possible" continuing for all repetitions or until failure. Furthermore, a 1RM for each subject had to be recorded. If subjects did not reach 1RM in the first five loads, the load was increased by 5kg until 1RM was found.

During baseline testing, the ten repetitions maximal power test in Keiser Pneumatic Leg-Press was used[21]. The load was calculated from 1RM achieved during familiarization. Beginning at a low resistance, subjects were instructed to push "as hard and as fast as possible" continuing for 10 repetitions (incremental increase in load per repetition) or until failure. Subjects were always aware of the next load they were attempting. For each effort, peak force, velocity and power were recorded for each leg. Upon completing F-v profiling, subjects got 2-3 minutes of rest before attempting a new 1RM. 1RM was achieved by progressively increasing the resistance by 5-10kg until they were unable to complete another lift. When a subject failed to complete a lift, the load was reduced by 5kg at a time in order to accurately determine their 1RM. Test-retest reliability of slope was examined between pre-test 1 and 2 (CV=9.6%; ICC=0.81).

2.2.3 | Leg extension power test

Maximal power (P_{max}) was measured in a single-joint movement, using a unilateral leg extension machine (G200 Knee Extension Machine, David Health Solutions Ltd., Helsinki, Finland). Leg extension machine was adjusted to 90˚ at the knee joint for all subjects, and they were seated and strapped in at the hip, torso and shin to prevent any aided movement. Testing procedure consisted of a low velocity three-repetition warm-up, followed by three repetitions of high velocity, all at a low resistance (15 kg). After warming up, subjects performed two consecutive repetitions per leg, per load, starting with the right leg, and then the left leg. Subjects had to complete four incremental loads in total, starting at 15kg, and increasing to 20kg, 30kg, and finally 40kg. Subjects received 1-minute of passive rest between loads. Subjects were instructed to perform each repetition with maximum intended force and velocity, and to have a brief rest between the two repetitions. Test-retest reliability of P_{max} was examined between pre-test 1 and 2 (CV=4%; ICC=0.91).

2.2.4 | Electromyography and rate of force development

A wireless EMG module (MuscleLab: Ergotest Innovation AS, Stathelle, Norway) and a surface electrode (Ambu BlueSensor M, Ballerup, Denmark) was used to measure myoelectrical activity of the *rectus femoris* muscle and *vastus lateralis* muscle on both legs. Myoelectric activity was measured in a seated position with knee angle at 90˚ in a unilateral leg extension machine (G200 Knee Extension Machine, David Health Solutions Ltd., Helsinki, Finland). Hips, torso and shins were strapped in to prevent aided movement and ensure proper technique. To measure and evaluate myoelectric activity, subjects performed a maximum voluntary isometric contraction (MVIC). Peak EMG is based on the square root calculation (RMS), and reflects the mean power of the signal (+/- 250ms from peak measurement/signal). Subjects performed 3 repetitions of MVIC per leg, starting with the right leg. Each repetition was to be executed with maximum force and velocity and be held for 3-5 seconds. To prevent fatigue, subjects received 1-2 minutes of passive rest between each repetition. Two electrodes were attached side-by-side to each of the muscles. In order to gather EMG data as accurately as possible, the electrodes were attached after sites were shaven and cleaned. Sensor site was determined using a marker during ultrasound. Frequency of the EMG signal was set to 20-500 Hz bandwidth and sampling frequency was 200 Hz.

RFD was measured simultaneously from each repetition in the same test procedure by attaching a force sensor to the machine lever arm, connected to a desktop PC, using dedicated software (MuscleLab: Ergotest Innovation AS, Stathelle, Norway). Test-retest reliability for all measures was examined between pre-test 1 and 2. Peak EMG *rectus femoris* (CV=16%; ICC=0.69), Peak EMG *vastus lateralis* (CV=15%; ICC=0.75), RMA *rectus femoris* 0-30 (CV=33%; ICC=0.35), RMA *rectus femoris* 0-50 (CV=35%; ICC=0.38), RMA *rectus femoris* 0-100 (CV=38%; ICC=0.38), RMA *rectus femoris* 0-200 (CV=34%; ICC=0.35), RMA *vastus* *lateralis* 0-30 (CV=39%; ICC=0.35), RMA *vastus lateralis* 0-50 (CV=39%; ICC=0.52), RMA *vastus lateralis* 0-100 (CV=34%; ICC=0.50), RMA *vastus lateralis* 0-200 (CV=25%; ICC=0.46), RFD $peak_{20}$ (CV=13%; ICC=0.82), RFD 0-30 (CV=88%; ICC=0.42), RFD 0-50 (CV=79%; ICC=0.53), RFD 0-100 (CV=66%; ICC=0.52), RFD 0-200 (CV=17%; ICC=0.72).

2.3 | Statistical analysis

Statistical data analysis was completed in IBM SPSS 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). Data was tested for normality using the Shapiro-Wilk normality test. Paired t-tests were used for within-group comparisons to assess pre to post changes in all measurements, and between-group comparisons were made using independent sample t-test. An analysis of covariance (ANCOVA) was used to adjust for any baseline differences between groups. Data are presented as mean ± standard deviation, with 95% confidence interval. The level of significance was set to $p<0.05$. Test-retest reliability was calculated using CV and ICC from consecutive pairwise comparisons, i.e. test 1 versus test 2, as recommended by Hopkins[22]. Data were graphically presented using the software Prism 8 (San Diego, CA, USA, https://www.graphpad.com).

3 | Results

Subject characteristics at baseline are outlined in Table 1, characteristics were generally balanced, showing no significant baseline differences between training modalities ($p>0.05$). All 49 subjects completed the intervention with the required number of training sessions (minimum 80% attendance). Seven subjects (IT: four, BT: three) dropped out due to either injury, sickness or other work-related issues.

Table 1 Descriptive statistics at baseline

Characteristic	Main (n = 49)	Force training (n = 11)	Velocity training (n = 13)	Balanced approach (n = 25)	Individualized approach (n=24)
Age (years)	67.7±5.3	67.8±1.4	67.9±1.2	67±1.2	67.8±4.4
Height (cm)	178.9±7	178.2±2.4	179.7±1.4	178.8±1.6	179±6.4

Weight (kg)	83.4±10.5	79.3±3.4	88.2±2.3	82.6±2.2	84.3±10.7
Total fat mass	22.1±7.	20.1±2.4	24.6±2.3	21.7±1.3	22.5±8.3
Total lean mass	57.9±5.4	56±1.7	60.3±1.1	57.5±1.2	58.5±5.2
Attendance	19.5±1	19.2±1.3	19.9±0.27	19.5±0.89	19.6±0.96

Notes: Values are presented as mean ± *SD*.

P_{max} improved significantly within BT group (5.5±9.8%, p=0.010) compared with IT group (-0.2±6.2%, p=0.778) and its sub-groups of Force (1.2±6.1%, p=0.525) and Velocity (-1.3±6.3%, p=0.358) (Table 2), and a significant between-group difference was observed between BT and IT, and BT and Force ([Figure 1 A, B] p=0.019; p=0.028, respectively). A significant within-group difference observed in Peak RFD20 with BT (13±24.5%, p=0.023) compared with IT (1.1±16.6%, p=0.925) and its sub-groups Force (-3.7±9.7%, p=0.171) and Velocity (5.1±20.3%, p=0.604) (Table 2). A significant between-group difference in Peak RFD_{20} was observed between BT and Force (p=0.006) (Table 2).

Significant within-group difference observed with BT in time-interval $RFD_{50,\ 100,\ 200}$ ([Figure 2 B, C, D] 40±58.4%, p=0.030; 19±30.2%, p=0.006; 16±24%, p=0.001, respectively). No significant increase was observed within any group for RFD_{30}, a significant between-group differences for RFD_{50} and $_{200}$ was observed between BT and IT ([Figure 2 B, D] p=0.045; p=0.012, respectively).

IT group and its sub-group velocity increased significantly in Peak EMG *rectus femoris* ([Figure 3 A, B] 13.3±16.6%, p=0.008; 12.8±14.5%, p=0.013, respectively), but no between-group differences were observed (Table 2). Significant within-group increases in peak EMG *vastus lateralis* was observed with all groups (BT: 15.7±19.5%, p=0.000; IT: 17.3±18.6%, p=0.000; Force: 20.6±19.4%, p=0.005; Velocity: 14.5±18.2%, p=0.026), but no between-group differences observed (Table 2).

No significant within-group differences observed with any group for RMA_{30}, $_{50}$, $_{100}$ *rectus femoris*, no significant between-group differences either. Significant within-group increases observed with BT, IT and its sub-group Velocity in RMA_{200} *rectus femoris* ([Figure 4 D] 19±37.5%, p=0.035; 23±31.8%, p=0.000; 23±17.1%, p=0.000, respectively). No significant within-group difference was observed with any group in RMA_{30}, $_{50}$ *vastus lateralis*. Only IT increased significantly in RMA_{100} *vastus lateralis* ([Figure 5C] 31±43.5%, p=0.015). All groups increased significantly from pre- to posttest in RMA_{200} *vastus lateralis* ([Figure 5 D] BT: 22±31.3%, p=0.010; IT: 29±31%, p=0.000; force: 31±30%, p=0.008; velocity: 27±32.9%, p=0.026).

Table 2 Percentage change with 95% CIs from pre-to post-test

Dependent variable	**Force**	**Velocity**	**Balanced**	**Individualized**	
	Within-group difference (95% CI)	**Within-group difference (95% CI)**	**Within-group difference (95% CI)**	**Within-group difference (95% CI)**	**Between-group difference (95% CI)**
P_{max}	1.2 (-2.4, 4.8)	-1.3 (-4.7, 2,1)	5.5 (1.7, 9.3) #	-0.2 (-2.6, 2.3)	BT vs IT -5.7 (-10.4, -1) * BT vs Velocity -6.8 (-12.8, -0.7) *
Peak RFD_{20}	-3.7 (-9.4, 2.1)	5.1 (3.4, 22.6)	13 (3.4, 22.6) #	1.1 (-5.6, 7.7)	BT vs Force -16.5 (-32.1, -0.9) *
Peak EMG *rectus femoris*	14 (2.4, 25.5)	12.8 (4.9, 20.6) #	20.7 (3.1, 38.4)	13.3 (6.7, 20) #	
Peak EMG *vastus lateralis*	20.6 (9.1, 32.1) #	14.5 (4.6, 24.3) #	15.7 (8.1, 23.4) #	17.3 (9.8, 24.7) #	

Notes: # significant within-group change, p<0.05; * significant between-group difference, p<0.05
Abbreviations: P_{max}, Maximal power; RFD_{20}, Rate of force development 20ms window; EMG, Electromyography; BT, Balanced training group; IT, Individualized training group; CI, Confidence interval.

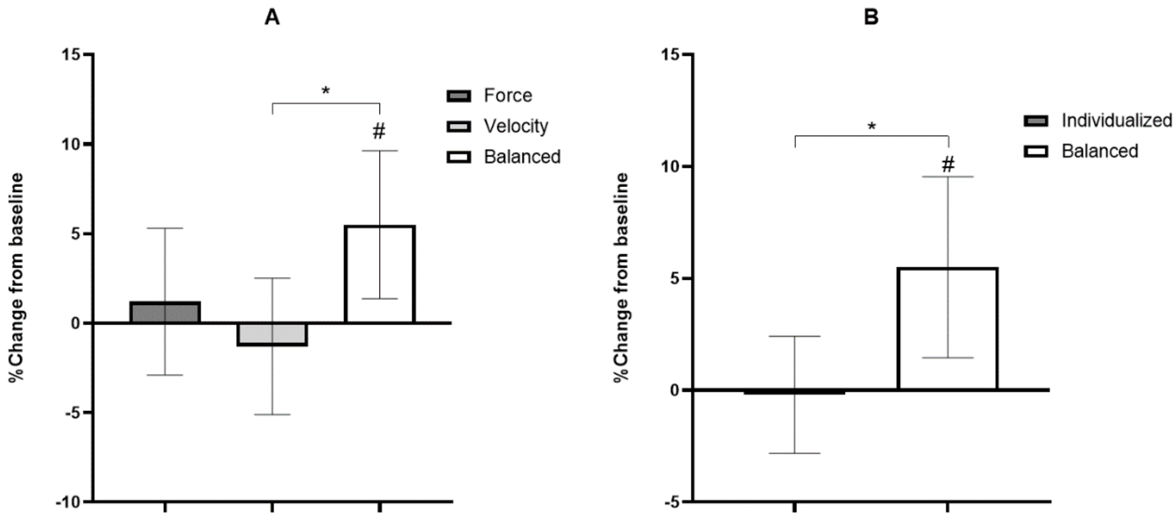

Figure 1 Percentage change from pre- to posttest in P_{max} for A=all groups and B=IT vs BT.

Notes: P_{max}, Maximal power; # significant within-group change; * significant between-group change.

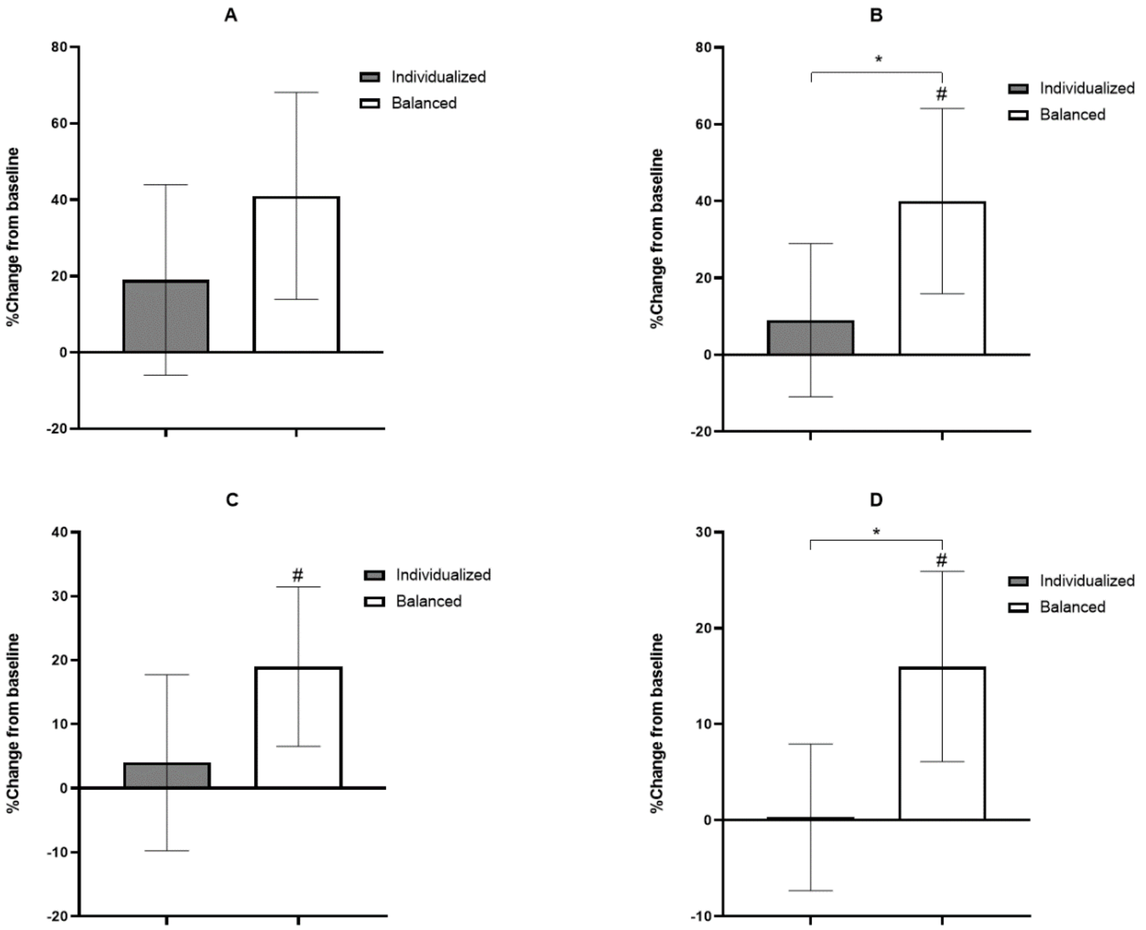

Figure 2 Percentage change from pre- to posttest between BT and IT in A=RFD_{30}, B=RFD_{50}, C=RFD_{100}, D=RFD_{200}.

Notes: RFD, Rate of force development. # significant within-group change; * significant between-group change.

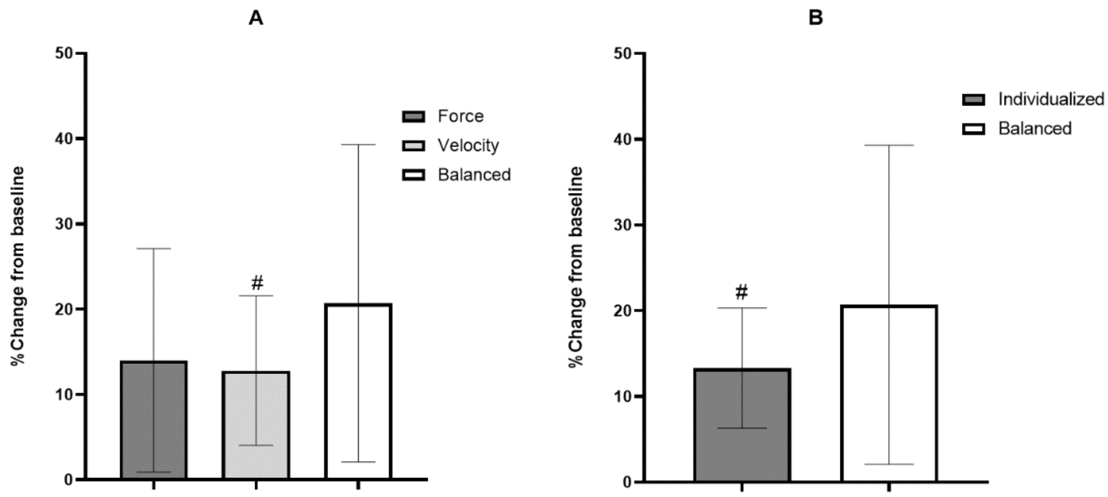

Figure 3 Percentage change in Peak EMG *rectus femoris* for A=all groups, B=IT vs BT.

Notes: EMG, Electromyography**.** # significant within-group change.

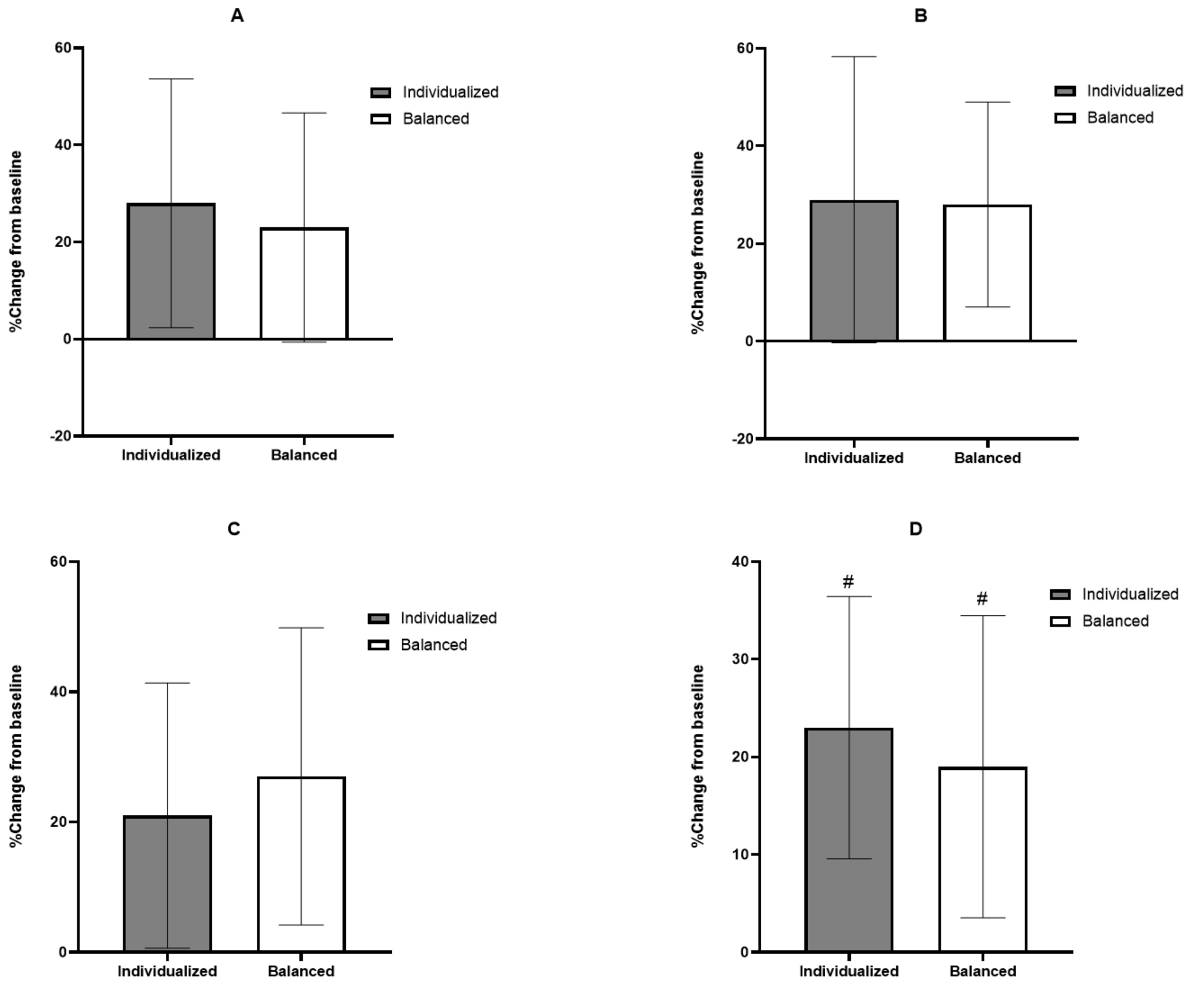

Figure 4 Percentage change for BT and IT in A=RMA_{30}, B=RMA_{50}, C=RMA_{100}, D=RMA_{200} *rectus femoris*.
Notes: RMA, Rate of myoelectric activity. # significant within-group change.

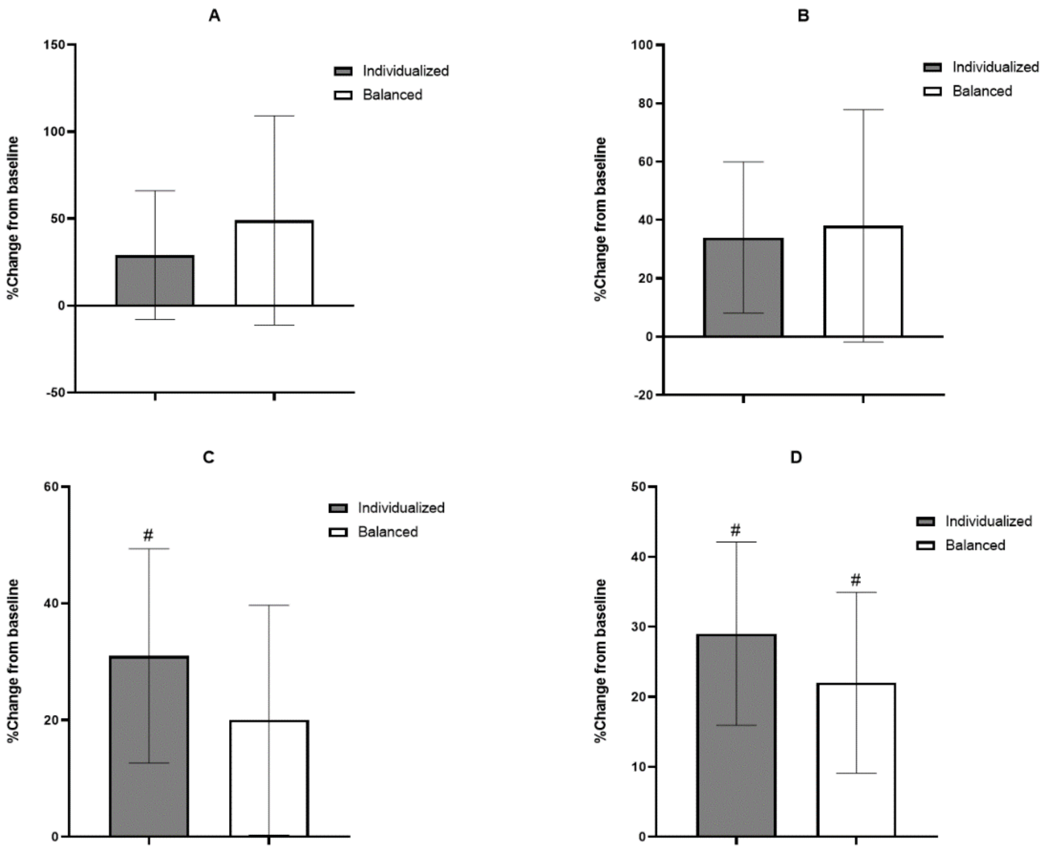

Figure 5 Percentage change for BT and IT in A=RMA_{30}, B=RMA_{50}, C=RMA_{100}, D=RMA_{200} *vastus lateralis*.
Notes: RMA, Rate of myoelectric activity. # significant within-group change.

4 | Discussion

The purpose of this study was to investigate the effects of an individualized power training program on P_{max}, RFD, myoelectric activity, and rate of myoelectric activity in older men compared with a balanced training approach. Given the importance of muscle power in physical functioning in older adults, and the steep rate at which it declines[2], improving muscle power is deemed a priority for preserving independence in later life[23]. A standardized resistance training program for improving muscle power among older adults is yet to be reported[24]. However, resistance training has generally proved to help mitigate decreases in neuromuscular function and functional capacity[16]. While there are studies investigating the effects of strength and power training in older adults[25,26], no other studies, to our knowledge, have studied the effects of an individualized approach to power training based on F-v profiles in an older population.

The results of this study suggest that a traditionally balanced power training approach is generally more effective compared with an individualized approach based on F-v profile for increasing muscle power and RFD in older men, which is unexpected. Ballistic performance is shown to be highly dependent upon the maximal power output generated by the lower limbs, as well as the individual combination of the underlying capabilities of force and velocity that make up the F-v profile[19]. Individuals are usually skewed towards one of these components, which may hinder optimal power production[19]. Improvements in muscle power, would in theory, be optimized by customizing a training program to focus on individual needs, decreasing this F-f imbalance[19].

Several studies investigating individualized power training have reported contradictory results compared with the present study[27, 28]. Granted the population, and the specific measurements were not the same, Escobar Álvarez et al.[27] investigated the effectiveness of a 9-week individualized F-v profile-based training during countermovement jumps (CMJ) in female ballet dancers. Results reported in this study showed significant differences in CMJ height, theoretical maximal force and velocity. They concluded that a training program addressing the F-v imbalance is an effective way to improve CMJ height in female ballet dancers. Jiménez-Reyes et al.[19] recently investigated whether an individualized training approach based on individual F-v profiles would improve vertical jump performance in trained athletes. They reported that training on individual deficits lead to improved jump performance. Another study[28] from 2015 with the aim of providing a practical vade mecum to readers on the use of an individualized training approach based on F-v profiling suggested that individual training programs would be most effective to improve ballistic performance in athletes[28]. However, one of the limitations they discussed is the fact that F-v profiling methods give information on *what* specific muscle power outputs should be developed (i.e. force versus velocity), but not *how* this should be done[28].

Following the training intervention only BT showed significant increases from pre- to posttest in P_{max}. Similar results are reported by de Vos et al.[29] investigating the optimal load for increasing muscle power during explosive resistance training in older adults. Subjects were to perform each repetition with maximum velocity. Results showed that heavy resistance training (80% 1RM) may be the most effective strategy to increase muscle power in older adults. Henwood et al.[30] reported in 2005 that a high-velocity (concentric phase) balanced training approach (training load 35-75% 1RM) significantly improved muscle power in healthy, independent older adults. Significant improvements in peak RFD_{20} was also only achieved in BT group. Similar results have been reported in contractile RFD after 14 weeks of heavy resistance training in young male adults by Aagaard et al.[14]. Tiggemann et al.[31] reported that there were no significant differences in RFD_{max} between a traditional strength training program and a power training program (training load: 45-65% 1RM) in healthy elderly women. A 2018 meta-analysis[32] reported that explosive resistance training is effective to promote significant RFD gains in elderly persons.

Data is less clear in terms of RFD and RMA, but BT group tends to display greater within-group improvements, which is in line with a study by Newton et al.[33] where it was reported that a resistance-training program combining exercises for increasing muscle mass, maximal force, and maximal power produced significant increases in maximal isometric strength, RFD, and EMG in both young and old men. Häkkinen et al.[34] reported similar results, showing that a combination of heavy resistance training and low load velocity training lead to improvements in explosive force production of the knee extensor muscles in both middle-aged and elderly men and women. They attributed results to the importance of neural adaptations to strength and power development in older adults[34]. Such neural adaptations can be attributed to performing a contraction with maximal intent, since without intent, maximal power (regardless of load) is not possible[35]. When measuring velocity during the training intervention, the velocity group tended to not always perform the contraction at the highest possible speed, which might help explain why the BT group were more likely to display significant increases in measurements.

Furthermore, there is a fundamental relationship between strength and power, dictating that a person cannot possess a high degree of power without being relatively strong to begin with[36]. Previous research investigating the effects of individualized power training based on F-v profiling[27, 19] did so in trained athletes, not older men with limited background in resistance training. This suggest that building a strong muscular basis in advance may provide a better fundament for individualized power training based on F-v profiling.

Reliability in both time-interval RFD and RMA in the present study can be considered poor, making it hard to assess the true effect of an individualized power training program based on F-v profiles. Although the test-retest reliability for peak RFD_{20} displayed good values (CV=13%; ICC=0.82), time-interval RFD showed high CV values (ranging from 66% to 88%) and low ICC values (ranging from 0.42 to 0.53). More of the same can be observed when examining test-retest reliability for myoelectric activity and rate of myoelectric activity. Test-retest reliability values for Peak EMG *rectus femoris* and *vastus lateralis* (CV=16%, ICC=0.69; CV=15%, ICC=0.75, respectively) may not be considered excellent, however, RMA *rectus femoris* (CV: ranging from 33% to 38%; ICC: ranging from 0.35 to 0.38) and *vastus lateralis* (CV: ranging from 25% to 39%; ICC: ranging from 0.35 to 0.52) values were rather poor in comparison.

The poor reliability in EMG measurements may be attributed to the placement of EMG surface sensors. Sensor sites were to be determined and marked during ultrasound; however, this was not always done, thus making the test much less reliable than needed. One of the consequences of this is physiological "cross-talk"[37], where neighboring muscles may produce a significant amount of EMG that is detected by the electrode. Although it typically does not exceed more than 10% to 15% of the overall signal, it may still interfere with the EMG recording[37]. Furthermore, results from a previous study suggest that proper surface electrode placement should follow the orientation of the muscle fiber[38].

According to the power analysis performed, target sample was 65 subjects (25 in each intervention group), including 15 subjects in a yoga-exercising control group. However, since subject participation did not meet the initial target sample size, the control group had to be removed. The termination of the control group places a limitation on the study since control groups provides an important comparison[39]. In addition, subjects and investigators had knowledge of which training group subjects were assigned to, making the study non-blinded, further increasing bias[40].

5 | Perspectives

We found that BT resulted in noticeably greater within-group improvements compared with IT in P_{max}, Peak RFD_{20}, and $RFD_{50, 100, 200}$, with no meaningful changes RFD_{30}. EMG measurements showed insignificant results with both training groups. Although contradictory compared to similar studies[19, 27] the results from the present study indicates that BT is a more beneficial training approach for increasing P_{max}, and RFD compared with IT based on F-v profiling in older men. Future research should limit the methodological limitation presented in the study, such as EMG surface electrode placement, having a control group, and blinding (either single- or double blinding) to decrease potential bias. Additionally, building a strong muscular basis may provide a different outcome. In the interim, caution should be exercised when recommending an individualized training approach based on F-v profiling in older men.

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The present study was conducted in collaboration with the University of Agder. A thank you to all subjects who participated in this study, your commitment and enthusiasm is admirable. Finally, I would like to acknowledge and thank everyone who contributed to this research project.

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Article Appendix

Table 12. List of tables and figures from article

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Table 2. Changes in P_{max}, Peak RFD_{20}, Peak EMG *rectus femoris*, Peak EMG *vastus lateralis*	**Figure 2.** Change in time-interval RFD
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List of Tables and Figures

Table 13. List of tables and figures from article

List of Attachments

1) Newspaper article

2) Recruitment poster

3) Information sheet

4) Subject consent form

5) Approval from the Norwegian Centre for Research Data

6) Approval from the Local Ethics Committee at the University of Agder

7) Health declaration form

Attachment 1: Newspaper article

UNIVERSITETET I AGDER

MANN 60+ SOM VIL BLI STERK?

Vil du være med i et forskningsprosjekt i regi av Institutt for idrettsvitenskap og kroppsøving ved UiA, hvor målet er å øke muskelstyrke, eksplosivitet og funksjon i et inspirerende treningsmiljø under veiledning av fagfolk med høy kompetanse!

Du inviteres til informasjonsmøte: Fredag 30.08 2019 kl. 17.00 i Aud. B1001 på Universitetet i Agder

INTERESSERTE BES TA KONTAKT MED:

Joachim S. Fjeller
tlf.: 415 89 285
(mand.-fred. 11.00-15.00)

eller

Sindre Fosstveit
tlf: 948 22 211
(mand.-fred. 10.00-15.00)

Attachment 2: Recruitment poster

Forsøkspersoner søkes

UiA Universitetet i Agder

MANN 60+ SOM VIL BLI STERK?

Vil du være med i et prosjekt, hvor målet er å øke muskelstyrke, eksplosivitet og funksjon i et inspirerende treningsmiljø under veiledning av fagfolk med høy kompetanse!

Alt er gratis!

Bakgrunn for studien

- Nyere studier har vist at individualisert tilpasset styrketrening er en effektiv treningsform for å øke fysisk funksjonsevne. Vi skal undersøke dette hos personer over 60 år

Fordeler med deltakelse

- Tett oppfølging av fagpersoner
- Tilgang på alle personlige testresultater
- Testing av blant annet fysisk funksjonsnivå, styrke og muskelmasse
- Innblikk i og bidrag til forskningsverdenen

Studien innebærer

- Trening to ganger i uken over ca. 12 uker
- Testing før og etter treningsperioden

Kriterier for å være med

- Vi søker menn mellom 60 – 90 år
- Ikke trent regelmessig styrke de siste 6 månedene (oppstart september 2019)
- Tilgjengelig for trening og testing på Spicheren/UIA, september – desember 2019

Eventuelle ulemper med deltakelse

- Treningen kan medføre en følelse av sårhet/stølhet i muskulaturen

Interesserte bes ta kontakt med mastergradsstudenter i idrettsvitenskap:

Joachim S. Fjeller tlf.: 41589285 (mand.-fred. 11.00-15.00) joachim.fjeller@gmail.com

eller:

Sindre Fosstveit tlf: 94822211 (mand.-fred. 10.00-15.00) sindrefosstveit@hotmail.com

Attachment 3: Information sheet

Vil du delta i forskningsprosjektet

"Kraft- hastighetsprosjektet og eldre"?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å se på effekten av powertrening på fysisk funksjons nivå hos eldre menn. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Mange eldre opplever at muskelstyrken er redusert sammenlignet med yngre år. Basert på forskning har man nå kunnskap om når i livet man er som sterkest og når det inntrer at man blir svakere, og ikke minst har man også nå kunnskap om hvorfor man blir svakere med økende alder.

Som 25-30 åring er man på sitt sterkeste, og etter dette reduseres maksimal muskelstyrken gradvis for hvert år. Her må det understrekes at tapet er mindre hos de individer som trener styrke regelmessig sammenlignet med de som ikke gjør det. Den største reduksjonen i muskelstyrke har man etter fylte 60 år, og ved 80-års alder er muskelstyrken nesten halvert sammenlignet med det man oppnådde som 25-åring. Redusert muskelstyrke hos eldre individer er ofte forårsaket av tapt muskelmasse, gjennom blant annet en reduksjon i størrelsen på eksisterende muskelfibre og reduksjon i antall muskelfibre. Tapet av muskelfibre ser dessuten ut til å være større i type II-fiber (raske muskelfiber) enn i type I-fiber (sene muskelfiber), noe som vil nedsette evnen til raske bevegelser og kraftproduksjon. Konsekvensen av disse endringer kan resultere i redusert funksjonsnivå, noe som også kan resultere i redusert livskvalitet for individet selv. Fysiske utfordringer i hverdagen som krever en viss muskelstyrke kan bli utfordrende, for eksempel å gå i trapper, forsere en høyde, løfte og bære tyngre gjenstander, hogge ved, reise seg opp fra stol og gange i mer eller mindre ulent terreng. Mange opplever også at balanse evnen forringes når man bli eldre, noe som kan ha sammenheng med kombinasjonen av redusert kraftutvikling i muskel og redusert impulshastighet i nervene. Man blir med andre ord både «svakere og tregere», og det tar lengre tid å gjenvinne en overbalanse. Benhelse ser også ut til å forringes grunnet økende alder i seg selv, i tillegg er inaktivitet en risikofaktor grunnet redusert belastning på skjelettet.

I den senere tid har forskerne hatt fokus på det man kaller for muskelpower, som er evnen til å utvikle stor muskelkraft i kombinasjonen med høy hastighet. Muskelpower ser ut til å reduseres mer enn muskelstyrke med økende alder. Det vil si ca. 3% reduksjon av power per år kontra ca. 1% reduksjon av styrke per år fra fylte 25-30 år. Forskning viser at det det ser ut til å være en sammenheng mellom økt muskelpower og forbedret funksjonsevne hos eldre. Sammenhengen mellom muskelpower og funksjon er større enn sammenhengen er mellom muskelstyrke og funksjon. Powertrening har vist å øke evnen til å utføre raske bevegelser, for eksempel gjenvinne balanse etter et hopp (overbalanse), samt å kunne krysse fotgjengerfeltet på «grønn mann» raskt nok. Et slikt treningsregime hvor hastighet på bevegelsen blir vektlagt vil trolig ha en større betydning enn maksimal styrke ved gjennomføring av slike daglige aktiviteter hos eldre. Muskelpower er trolig en mer overlegen indikator på fysisk funksjonsnivå hos eldre individer sammenlignet med maksimal muskelstyrke.

Siden muskelpower er avhengig av både muskelkraft og hastighet på bevegelsen, og forholdet mellom dem, har det vist seg at kraft-hastighetsforholdet (også kalt kraft-hastighetsprofil) vil være nyttig å ha fokus på når man utformer individuelt tilpasset trening og treningsprogram for idrettsutøvere for dermed å kunne påvirke idrettslig prestasjon best mulig. Her trekker man paralleller til eldre individer, der man ønsker å se på kraft- hastighets forholdet for å kunne tilpasse individuell power trening for derigjennom å påvirke funksjonen best mulig. Det vil si at man avdekker hva individet er svakest på, kraft eller hastighet, og trener dermed på nettopp dette.

Tidligere forskning har sett på effekter av det vi omtaler som tradisjonell powertrening (ikke individuelt tilpasset) hos eldre, men når det gjelder effekt av individuelt tilpasset powertrening (basert på kraft- hastighetsforholdet) hos eldre er det svært begrenset med forskning. Det er nettopp det som er bakgrunnen for dette prosjektet. I tillegg så gjenstår kunnskap om mulige årsaksforklaringer til eventuelt forbedret muskelpower og funksjonsnivå etter en periode med powertrening. Har disse eventuelle effekter noen sammenheng med endringer i muskel og nerve (muskelarkitektur og muskelaktivering) når eldre trener denne type individualisert power trening? Disse forhold ønsker vi også å belyse. I tillegg ønsker vi å undersøke om denne type trening kan påvirke helserelatert livskvalitet, balanseevne og benhelse.

Gjennom dette prosjektet ønsker vi å belyse følgende problemstilling:

> Hvilken effekt har individuell tilpasset powertrening sammenlignet med tradisjonell power trening på muskelpower, muskelstyrke, muskelarkitektur, muskelaktivering og fysisk funksjonsnivå hos eldre menn? I tillegg; hvordan påvirker disse to treningsregimer helserelatert livskvalitet, benhelse og balanseevne?
>
> I dette prosjektet vil det også bli forsøkt å utvikle en valid Smarttelefon App som kan brukes til testing og trening hvor eldre på en enkel og reliabel måte kan vurdere kraft-hastighetsforholdet og derigjennom trene muskelpower basert på individuell tilpasning. Med denne Appèn har vi også som mål å bruke som et eHelse verktøy. Med en slik App kan man trene på en sikker og korrekt måte hjemme alene eller sammen med venner helt uavhengig av test- og treningsekspertise.

Det blir gjennomført testing før og etter en 12-ukers treningsperiode, hvor det legges til rette for gruppetrening med instruktør to ganger per uke. Deltakerne randomiseres (tilfeldig loddtrekning) i tre grupper; kontrollgruppe som får tilbud om yoga, individuell tilpasset powertreningsgruppe og tradisjonell powertreningsgruppe.

Dette er en del av et forskningsprosjekt hvor det inngår en doktorgrads studie og fem mastergrads studier.

Hvem er ansvarlig for forskningsprosjektet?

Universitet i Agder, Institutt for idrettsvitenskap og kroppsøving er ansvarlig for prosjektet.

Under vises en oversikt over samarbeidspartnere/-institusjoner.

Institution	International collaborators	Role description
UU	Dr. Ingrid Demmelmaier	Expert in behavior and lifestyle change
Institution	**National collaborators**	**Role description**
UiA/UU	Prof. Sveinung Berntsen*	PI, Expert in exercise oncology, physical activity and health
UiA	Dr. Hilde Lohne-Seiler	Expert in strength training of elderly
UiA	Prof. Monica K. Torstveit	Expert in bone health
UiA	Thomas Bjørnsen Phd (c)	Expert in exercise physiology
UiA	Dr. Bjørge H. Hansen	Expert in measures of physical activity
UiA	Dr. Kristin Haraldstad	Expert in health-related quality of life
UiA	Dr. Folke Haugland	Expert in computer programming
UIA	Kolbjørn Lindberg, MSc	Expert in force-velocity measurements
NIH/UiA	Prof. Truls Raastad	Expert in muscle physiology
NIH/OLT	Dr. Gøran Paulsen	Expert in exercise physiology/power training
NIH	Prof. Olivier Seynnes	Expert in ultrasonography

UU, Uppsala University; UiA, University of Agder; NIH, Norwegian School of Sport Sciences; OLT Olympiatoppen

Hvorfor får du spørsmål om å delta?

Du som får dette brevet er mann 60 år og eldre. Du har din hjemstedsadresse i Kristiansand og omegn. Du har fått informasjon om dette prosjektet via annonse i Fædrelandsvennen, eller gjennom «flyers» delt ut i ditt nærmiljø. Du har deltatt på vårt første informasjonsmøte som ble holdt i UiA`s lokaler. På dette møtet kom det blant annet frem at for å kunne delta må det innhentes en helseerklæring fra din fastlege som bekrefter at du ikke lider av noen form for sykdom eller har andre lidelser som gjør deg helsemessig forhindret fra å bli inkludert som deltaker i dette prosjektet. Det vil si at du helsemessig må være «klarert» for å kunne bli inkludert i prosjektet som skal se på effekter av powertrening. Du må ikke trene annen form for styrke- eller power trening i den perioden som prosjektet foregår. Totalt skal det inkluderes 65 eldre menn over 60 år. Etter tilvenning og gjennomgang av alle førtester randomiseres (tilfeldig loddtrekning) alle deltakerne i en av tre grupper, som også tidligere beskrevet i dette informasjonsskrivet; 1) kontrollgruppe som får tilrettelagt yoga (antall deltakere: 15), 2) individuell tilpasset powertreningsgruppe (antall deltakere: 25) og tradisjonell powertreningsgruppe (antall deltakere: 25).

Alle potensielle deltakere vil motta informasjonsskriv (dette du nå leser), i tillegg til å bli invitert på informasjonsmøte. Det gis også ut en samtykkeerklæring som signeres av den enkelte deltaker (se dette skjemaet på slutten av infoskrivet).

Hva innebærer det for deg å delta?

Hvis du velger å delta i prosjektet, innebærer det at du fyller ut et spørreskjema. Det vil ta deg ca. 45 minutter. Spørreskjemaet inneholder spørsmål om livskvalitet knyttet til sosial, fysisk og mental funksjon.

Det innebærer også at du går igjennom et testbatteri bestående av fysisk testing. Det samme testbatteriet gjennomføres før (pre) og etter (post) selve treningsperioden, og vil deles opp i to testdager under både pre- og posttesting. Totalt vil testingen vare 5 timer (begge dager inkludert).

Oversikt over tester Test Dag 1:

- Ultralyd (muskeltverrsnitt, tykkelse, pennasjonsvinkel, fasikkellengde, muskelkvalitet)
- Gripe styrke
- Kraft- hastighetsprofil, Legg press (Keiser) + 1RM (max styrke)
- Kraft- hastighetsprofil, "Sit-to stand power test" (opp og ned fra stol)
- Kraft- hastighetsprofil, Benkpress + 1RM (1080 Quantum)
- Trappe test

Oversikt over tester Test Dag 2:

- Dexa (benhelse)
- Balanse test
- "The Timed "Up & Go" test" (på start signal; fra sittende posisjon gå 2.45 m så fort som mulig, forsere en kjegle, gå så tilbake så fort som mulig til utgangsposisjon)
- Box lift test (løfte en kasse med belastning)
- Skulder press
- Kraft- hastighetsprofil, Legg ekstensjon
- EMG (elektromyografi); muskelaktivering, Legg ekstensjon

Dine svar fra spørreskjema og resultater fra fysisk testing blir registrert elektronisk.

Alt datamateriale som registreres anonymiseres.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Det er kun PhD kandidat, master studenter og veiledere ved behandlingsansvarlig institusjon (UiA) som vil ha tilgang til opplysningene om deg.
- Navnet og kontaktopplysningene dine vil jeg erstatte med en kode som lagres på egen navneliste adskilt fra øvrige data. Alt datamateriale vil bli lagret på en egen forskningsserver.

Du vil ikke bli gjenkjent i noen form for publikasjon, så fremt ikke du har gitt ditt samtykke til at vi kan benytte bilde av deg som er tatt i forbindelse med trening eller testing.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Prosjektet skal etter planen avsluttes innen utgangen av juli 2020. Ved prosjektslutt skal alt datamaterialet anonymiseres (innen utgangen av juli 2020).

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Universitetet i Agder har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Prosjektleder; Professor Sveinung Berntsen Stølevik, sveinung.berntsen@uia.no, telefon +47 38 14 10 45 eller Førsteamanuensis Hilde Lohne-Seiler, hilde.l.seiler@uia.no, telefon +47 38 14 12 89

- Vårt personvernombud: Ina Danielsen, Universitetet i Agder, ina.danielsen@uia.no, telefon +47 452 54 401
- NSD – Norsk senter for forskningsdata AS, på epost (personverntjenester@nsd.no) eller telefon: 55 58 21 17.

Med vennlig hilsen

Prosjektansvarlig

(Forsker/veileder)

Attachment 4: Subject consent form

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet; "Kraft- hastighetsprosjektet og eldre», og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i registrering av helserelatert livskvalitet og fysisk testing

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet, innen utgangen av juli 2020.

(Signert av prosjektdeltaker, dato)

Attachment 5: Approval from the Norwegian Centre for Research Data

NSD Personvern
30.08.2019 09:08

Det innsendte meldeskjemaet med referansekode 923574 er nå vurdert av NSD.

Følgende vurdering er gitt:

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet den med vedlegg, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde: nsd.no/personvernombud/meld_prosjekt/meld_endringer.html
Du må vente på svar fra NSD før endringen gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle særlige kategorier av personopplysninger om helseforhold samt alminnelige kategorier av personopplysninger frem til 31.07.20.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 nr. 11 og art. 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse, som kan dokumenteres, og som den registrerte kan trekke tilbake.

Lovlig grunnlag for behandlingen vil dermed være den registrertes uttrykkelige samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a, jf. art. 9 nr. 2 bokstav a, jf. personopplysningsloven § 10, jf. § 9 (2).

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).

NSD vurderer at informasjonen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og eventuelt rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Kontaktperson hos NSD: Silje Fjelberg Opsvik
Tlf. Personverntjenester: 55 58 21 17 (tast 1)

Attachment 6: Approval from the Local Ethics Committee at the University of Agder

Hei
Her er utdrag fra protokoll fra møte i Forskningsetisk komité i Fakultet for helse- og idrettsvitenskap, fra 19.08.2019, og det bekreftes med dette at følgende søknader er behandlet og godkjent:

Effekten av et individualisert power treningsprogram på maksimal power, hastighet på kraftutvikling, muskelaktivering, og hastigheten på muskelaktivering hos eldre menn - master - Erlend Eugenio Sibayan
Søknad godkjennes

Vennlig hilsen

Eli Andås
Ph.d.- og FoU-rådgiver/PhD and Research Adviser
Fakultet for helse- og idrettsvitenskap/Faculty of Health and Sport Sciences
UiA / University of Agder

eli.andas@uia.no
Tlf: 38 14 18 66 / 928 27 770

https://www.facebook.com/Helseidrett/?fref=ts

Attachment 7: Health declaration form

Til fastlegen

Gjelder deltakelse i «Kraft- hastighetsprosjektet og eldre» i regi av Institutt for idrettsvitenskap og kroppsøving» ved Universitetet i Agder.

Jeg bekrefter herved at jeg har lest informasjonsskrivet om «Kraft- hastighetsprosjektet og eldre». På bakgrunn av disse opplysningene, finner jeg ___________________________________ (navn på din pasient) helsemessig klarert for prosjektet og anbefaler derfor hans deltakelse.

Sted:

____

Dato:

____

Navn på fastlege (bruk blokkbokstaver) / signatur:

Førsteamanuensis Hilde Lohne-Seiler ved Institutt for idrettsvitenskap og kroppsøving ved UiA kan kontaktes dersom det er behov for ytterligere opplysninger: hilde.l.seiler@uia.no / 381 41 289