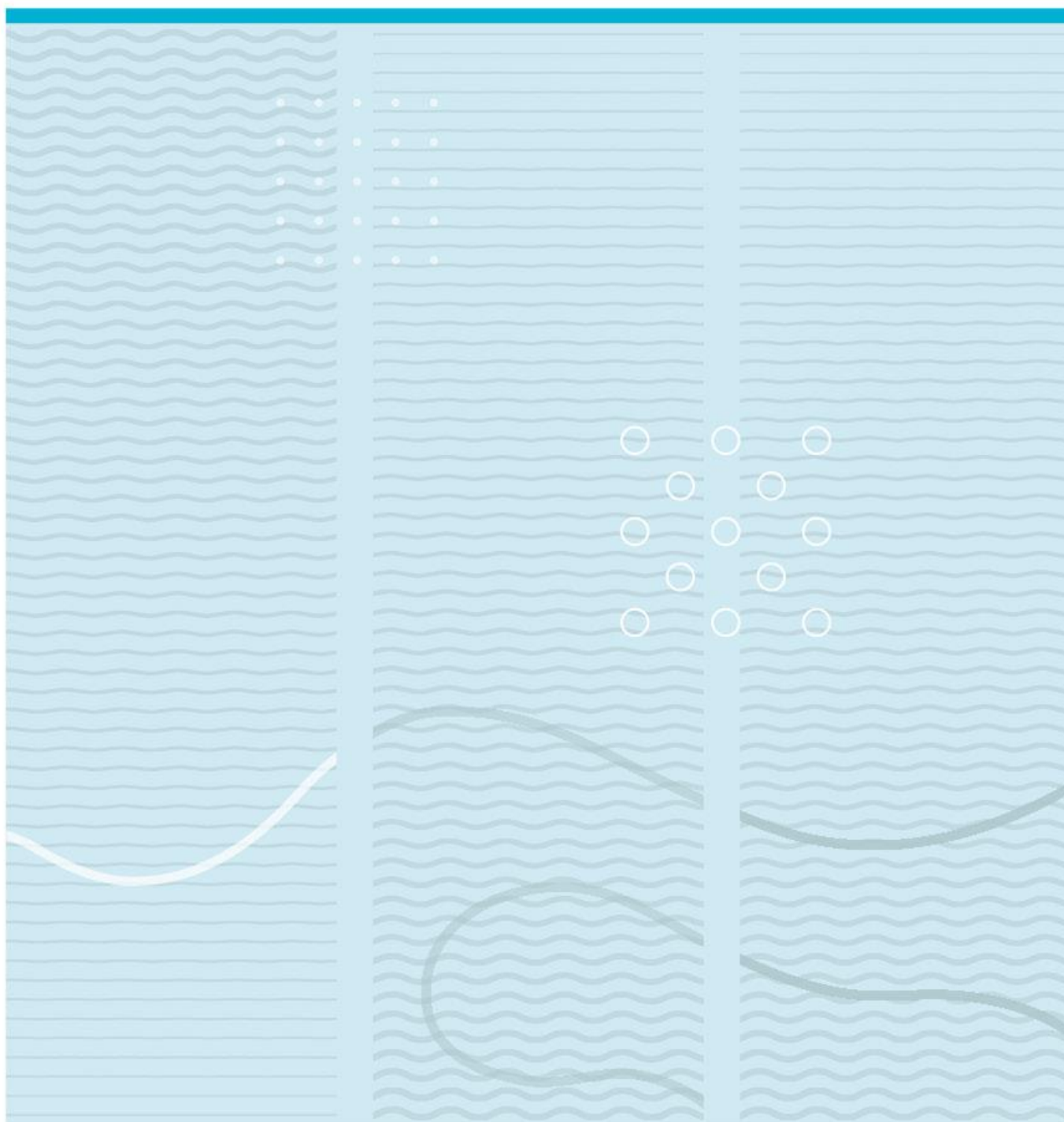


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Never too old.

Does age affect strength adaptations to MST?



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This thesis is worth 60 study points

Abstract

Background: To reduce risk of age-related consequences of strength and muscle atrophy, strength training has been recommended as a feasible and effective strategy. However, there is still lack of research about maximal strength training (MST) in old. Therefore, the purpose of this master thesis was to investigate if muscle strength adaptations after MST were affected by age.

Methods: Seventy-six subjects (20-77 years) were divided into 5 age-groups. Forty-nine of these subjects completed a four times four repetitions maximum, three times per week leg press training program for eight weeks. To examine changes in muscle strength, one repetition maximum (1RM) in leg press was measured prior- and after the training intervention.

Results: One repetition maximum leg press increased in all age-groups, with a mean improvement of 24% ($P < 0.05$). No significant differences were found between age-groups. The improvements were independent of genders.

Interpretation: These results suggest that leg press MST can induce positive strength adaptations at all ages. Therefore, maximal strength training should be recommended to older adults to promote health and functionality.

Keywords: maximal strength training, muscle strength, aging, leg press, older adults

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Bø i Telemark, may 2019

Monika Szaynok

List of abbreviations

± SD – standard deviation

ATP – adenosine triphosphate

BMC – bone mineral concentration

BMD – bone mineral density

BMI – body mass index

BW – body weight

CON - concentric

CSA – cross sectional area

ECC - eccentric

GLM – general linear model

HRQOL - health-related quality of life

MST – maximal strength training

MUDR - motor unit discharge rate

PCr - phosphocreatine

RFD – rate of force development

RM – repetition maximum

SR – sarcoplasmic reticulum

ST - strength training

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1.0 Introduction

Age-related muscle atrophy and strength decrease are important issues in gerontology and geriatrics. Consequences such as reduced functional independence, higher risk of hospitalization, greater risk of falls and bone fractures are related to strength loss, and may negatively affect the quality of life and economy (Frontera et al., 2000). Osteoporosis results reduced functionality, and increased governmental costs to take care of such patients. Only in the United States, costs up to 20 billion dollars have been linked to osteoporosis (Brown & Josse, 2002).

Previous studies have expressed evidence for the importance of applying resistance training to counterattack age-related declines in physical function (Brown & Josse, 2002; Lofman et al., 2002; Botero et al., 2013; Sözen et al., 2016). According to the American College of Sports Medicine (2010), progressive resistance training is recommended to decay or reverse the age-related structural and functional neuro-muscular changes. Moreover, with early treatment, even osteoporosis can be reduced or even prevented by applying adequate resistance training (Sözen et al., 2016). Long-term strength training can sustain and improve general fitness in an elderly population, contributing to functional performance and enhancing the quality of life (Haraldstad et al., 2017).

Several studies have shown strength training adaptations also in elderly, i.e. above 60 years old (Patten et al.; 2000, Kosek et al., 2006; Wang et al., 2017). Findings of Kosek et al. (2006) and Patten et al. (2000) reveal that older adults have responded to maximal strength training (MST) at >80% one repetition maximum (RM), and have restored muscle mass even to a similar level as active young after only 3-4 months (Kosek et al., 2006). Likewise, Wang et al. (2017) have shown improved 1RM, rate of force development (RFD), and work efficiency in elderly above 70 years old. In Wang et al. (2017), the improvements resulted in muscular strength post intervention almost equal to young untrained controls. Based on results from previous studies, it thus seems important to implement MST when planning health promotion efforts targeting older adult, as proposed in Haraldstad et al. (2017).

The present study therefore aimed to investigate impact of maximal strength training (MST) on different age-groups (20-70+ years old). In order to do this, a MST intervention, using four times

four repetitions maximum, three times per week for eight weeks was applied. The training intervention was to be a supplement to the participant's normal activity level. By analysing results from the MST intervention, the effect of maximal strength training for older adults (60+ years) compared to younger adults (20-29 years) could be possible. The following research questions were addressed in this master thesis:

Main research question

Does age affect strength adaptations to MST?

Sub research questions

Do older adults and young adults differ significantly in absolute, and relative (%) training response to MST?

To what extent is chronologic age and or a more sedentary life-style influencing on reduced muscular strength in elderly?

The latter question was discussed theoretically in this thesis, but was not aimed to be answered from the present intervention data alone.

2.0 Theory

One repetition maximum is one maximal effort, used to measure the net external force result of an action, and thus indirectly muscular strength (Kraemer et al., 2006; Knudson, D.V., 2007, *Fundamentals of Biomechanics*). MST can lead to significant improvements in muscle strength expressed by this variable (Campos et al., 2002). These changes are associated with both muscular and neural adaptations (Kraemer & Ratamess, 2004). Adaptation to training stimuli is often labelled trainability, and indicate the plasticity of both the nervous system and myofibrillar system (Norris & Smith, 2002).

Age-related decrease in muscle mass and atrophy of type II fibres have been shown to result in decreased RFD (Harridge, S.D., 1996; Vidt et al., 2012). A reduced RFD naturally lead to worse balance, higher risk of fall, premature mortality and lower quality of life (Gomes et al., 2013; Maden-Wilkinson et al., 2015). Maintenance of both muscle mass and strength in elderly seems therefore essential for preventing age-associated diseases (sarcopenia, osteoporosis, obesity) and promoting healthy aging (Persh et al., 2009; Mosti et al., 2013; Wang et al., 2017).

Previous studies have shown that MST increased the strength training modality that has led to the greatest improvements in 1RM, RFD and power (Campos et al., 2002; Reid et al., 2013; Thompson et al., 2014; Maden-Wilkinson et al., 2015; Unhjem et al., 2015; Marzetti et al., 2017; Richardson et al., 2018). One of the very first MST studies that showed improvements in 1RM in old aged subjects, was the work of Frontera et al. (1988, 1991). Since then, more studies have addressed this area of research. Even if older people may have a different response to MST when comparing to the young-group individuals, several studies have brought the arguments that MST brings both morphological and neural improvements in elderly (Brentano et al., 2008; Fimland et al., 2009; Unhjem et al., 2015; Wang et al., 2017). However, there is still only limited data about how muscle strength, neural system, body composition and the quality of life may be altered by MST in elderly subjects.

2.1 Maximal muscular strength

According to Bompa et al. (2012), maximal muscle strength is the highest force that can be performed by the neuromuscular system during a maximum contraction. This implies 100 percent of maximum, or one-repetition maximum (1RM), the maximal force that muscle or the muscle group can generate at a given speed, exerted in one maximal effort. Knowledge of 1RM is important for training purposes, as it is the basis for calculating loads for every strength phase and the later progression.

The potential for muscular strength is given by the muscles' cross sectional area (CSA) (Maughan et al., 1982). The ability to utilize this potential is dependent on the ability to create cross-bridges, which is dependent on the amount of Ca^{++} release from the sarcoplasmic reticulum, which again is dependent on the recruitment of moto-neurons and the firing frequency through the axon (Chin et al., 1988). In order to contract (sliding filaments), sufficient ATP must be available, and the reformation of ATP depends on the speed of the metabolism (Baker et al., 2010; Westerblad et al., 2010).

2.1.1 Cross sectional area

The larger CSA, the bigger the muscle mass attached to the tendon, and the greater strength capacity (Raastad et al., 2010). The most important in this case is that CSA can be improved with training, first and foremost by increasing the CSA of the different muscle fibres (Campos et al., 2002).

Muscle fibres in the human body are classified into three main groups: type I (slow twitch) and type IIa and IIx (fast twitch) (Grimby, G., 1990; Howley & Zierath, 2004; Westerblad et al., 2010). Type I are the most economical, and thus recruited first in the recruitment hierarchy (Howley & Zierath, 2004; Westerblad et al., 2010; Tieland et al., 2017). They have good oxidative capacity, but are not able to produce much force during fast contractions. Type IIa have relatively good oxidative capacity, and are thus recruited secondly in the recruitment hierarchy (Grimby, G., 1990; Howley & Zierath, 2004; Westerblad et al., 2010). They have a

better ability than type I fibres for producing force during fast contractions (Howley & Zierath, 2004; Westerblad et al., 2010; Tieland et al., 2017). The least economical fibres are type IIX (Howley & Zierath, 2004; Westerblad et al., 2010). These fibres are recruited last in the recruitment hierarchy (Howley & Zierath, 2004; Westerblad et al., 2010; Tieland et al., 2017). They have a great ability for producing force during fast contractions, but very low oxidative capacity (Grimby, G., 1990; Howley & Zierath, 2004; Westerblad et al., 2010). Due to the latter, IIX fibres tend to change into IIA after resistance training, while the relative proportions of type I and type II fibres in general not seem to change (Campos et al., 2002). What is important, the genetically inherited proportion of type II fibres determines predispositions towards strength training, by being capable of quicker and more powerful contractions (Howley & Zierath, 2004; Westerblad et al., 2010).

CSA determines the strength potential, due to the number of cross bridges that are parallel in the muscle (Morgan & Proske, 1999; Bestel et al., 2001; Raastad et al., 2010; Westerblad et al., 2010). The greater CSA, the larger number of cross-bridges, and the stronger muscle tension is observed (Huxley & Simmons, 1971; Bestel et al., 2001; Ahtiainen et al., 2003; Westerblad et al., 2010). Importantly, CSA can be improved by resistance training (Campos et al., 2002; Ahtiainen et al., 2003; Kanegusuku et al., 2015; Wang et al., 2017). The most effective type of resistance training in order to improve CSA has been shown to be training that puts the most stress on both the metabolic and the mechanical systems, i.e. 8-12 RM (Campos et al 2002; Kraemer & Ratamess, 2004; Schoenfeld et al., 2016).

2.1.2 Ca⁺⁺ release

The nervous system sends nerve impulses to the muscle fibres by the motor nerves (Bompa et al., 2012, *Serious Strength Training. Third Edition*; Westerblad et al., 2010). One motor unit consists of a motor axon and the muscle fibres it innervates (Freund et al., 2003; Melis & Pistis, 2007; Westerblad et al., 2010; Flores et al., 2013). One of the first adaptations from resistance training is the ability to recruit more, and after a while, all motor units needed in a maximal contraction (Mrowczynski & Lochynski, 2014). Nerve signals travel down the axon of the recruited motor units by depolarization and repolarization across the axon membrane (Freund et al., 2003; Melis

& Pistis, 2007; Flores et al., 2013). If above the action potential, these signals cross the synaptic junction and proceed along the muscle fiber membrane, into the T-tubuli, and finally releases Ca^{++} from SR (Nakajima & Endo, 1973; Westerblad et al., 2010; Tieland et al., 2017). The number of action potentials per time unit (frequency) determines the amount of Ca^{++} release (Nakajima & Endo, 1973; Westerblad et al., 2010). As Ca^{++} is necessary for revealing the binding site on actin for the myosin head, the higher firing frequency, the greater release of Ca^{++} , and the larger number of cross-bridges (Bestel et al., 2001; Westerblad et al., 2010). So, the greater the signal to initiate the Ca^{++} release, the greater utilization of the force potential given by CSA (Du & McCormick, 2009, *Applied Muscle Biology and Meat Science*, p. 21-50; Westerblad et al., 2010). As with CSA, also the firing frequency can be improved by resistance training (Aagaard, P., 2003; Gabriel et al., 2006; Mrowczynski & Lochynski, 2014). The most effective training to improve firing frequency has been shown to be training with maximal voluntary mobilization, i.e. MST (Campos et al., 2002; Gabriel et al., 2006; Westerblad et al., 2010).

2.1.3 ATP reformation

ATP is the basic and immediate energy source that plays a major role in energy conversion for muscle cross-bridge cycling (Westerblad et al., 2010). When released Ca^{++} has contributed to cross-bridges, each myosin head needs to be loaded by one ATP in order to push and then release from actin and thus create the sliding filament movement (Bestel et al., 2001). For the initiation of one single maximal contraction, the muscles may have sufficient ATP stored, but as soon as cross-bridge cycling or even contractions are repeated, reformation of ATP is necessary (Sugi et al., 2008; Tieland et al., 2017). For this reason, the faster the process of ATP resynthesis, the better ability for maximal muscle performance. In high-intensity/low-repetitions sets with rest intervals of 3-5 minutes, the main energy source for ATP resynthesis is creatine phosphate (PCr) (Baker et al., 2010; Westerblad et al., 2010). This is the fastest energy turnover system, but limited availability for PCr limits maximal work depending on this system alone to approximately 15 seconds (Bogdanis et al., 1996; Westerblad et al., 2010). To resynthesize PCr fully, normally takes 1-4 minutes, depending on aerobic endurance (Baker et al., 2010; Westerblad et al., 2010). Also, with training, the PCr stores can be expanded. As the PCr

availability decreases during resistance training or testing, ATP reformation is more and more dependent on the glycolytic system (Volpi et al., 2004; Baker et al., 2010; Westerblad et al., 2010). This system is slower, but has the ability to provide sufficient energy for ATP reformation during maximal work for about 30-40 seconds (Bogdanis et al., 1996; Casey et al., 1996). Unfortunately, this system also produces the bi-product lactic acid, decreasing muscle pH and thus a less optimal milieu for fast chemical processes (Gladden, L.B., 2004; Baker et al., 2010; Westerblad et al., 2010). Also the velocity of ATP reformation can be improved by resistance training (Westerblad et al., 2010; Berg et al., 2018). Enzymes responsible for energy turnover, such as glycolytic enzymes can increase in number, and become more efficient with training (Bouchard et al., 1991; Hargreaves & Hawley, 2003, *Physiological bases of sports performance*; Bompa et al., 2012, *Serious Strength Training. Third Edition.*).

2.2 The importance of maximal strength in daily life

With aging, all changes in body composition, muscle size, muscle strength, and neuromuscular activation that occur, may affect the performance of daily tasks. Studies show that daily activity level decreases with aging (Mau-Moeller et al., 2013). Therefore, it seems important to take a closer look on those age-related alterations, how they may be affecting functionality, health and mortality.

2.2.1 Functionality

Effect of aging is visible on quality of life, where functional limitations on daily tasks and leisure activities may cause lifestyle implications (Lindle et al., 1997; Daly et al., 2013). Sarcopenia appears to be a major health issue in elderly (Azzabou et al., 2015). Sarcopenia is age-associated muscle atrophy due to gradual reduction in the release of sex hormones and / or reduced activity level, leading to loss of strength and mobility (Romero-Arenas et al., 2013). Castillo et al. (2013) have reported that the amount of people with sarcopenia is increasing severely after 65 years of age, and this may be the main contributing factor to limited physical performance and independence. Marzetti et al. (2017) observed that individuals above 80 years had approximately

10% less muscle mass and 20% lower muscle strength compared to young. Impaired strength deteriorates accomplishment of daily physical tasks and thus quality of life. In order to counteract these negative changes, resistance training has proven a useful task (Wang et al., 2017). In studies by Fiatarone et al. (1990, 1994), both muscle strength, CSA and muscle mass increased in elderly after resistance training interventions. Strength enhancement was found to improve gait velocity, increased level of spontaneous activity, and reduced risk of falls (Fiatarone et al., 1990, 1994; Persch et al., 2009). Moreover, systematic strength training has been shown to reverse age-related decreases in agonist activation (Reeves et al., 2004), as well as efferent neural drive (Unhjem et al., 2016). Therefore efforts to mitigate age-related deteriorations are necessary for older adults' wellbeing and independence.

2.2.2 Bone health

Osteoporosis (bone loss) is one of the consequences of aging. The general bone weakness is linked to the greater risk of fractures, resulting in functional limitations in daily life and leisure activities (Lindle et al., 1997; Daly et al., 2013). Mortality rate associated with hip fracture is among elderly higher than the risk related to breast cancer (Brown & Josse, 2002). It has been estimated that 1 in 3 women will suffer from osteoporotic fractures during their life span (Brown & Josse, 2002). Although more frequent in women, particularly in men, osteoporosis has been closely linked to the mortality rate (Sözen et al., 2016).

Strength training could be used as a tool strategy to lower injury risk and mortality rate in older adults by preventing or reducing a deteriorated bone mineral density (BMD). Some studies have proven that MST can improve skeletal properties in middle-aged patients (Kerr et al., 1996; Cussler et al., 2003; Mosti et al., 2013). In Mosti et al., (2013). For instance bone mineral content (BMC) increased significantly in postmenopausal women after 12 weeks of MST, showing great potential in osteoporosis treatment (Mosti et al., 2013).

2.2.3 Direct and indirect effect on general health

Various health benefits may come as the result of improved muscular fitness. Decreased risk of falls, increased activity level with effect on cardio-vascular and metabolic function, decreased risk of osteoporosis, decreased risk of certain types of cancer (colon, breast) are only some of those outcomes (Fiatarone et al., 1990, 1994; Brentano et al., 2008; Persh et al., 2009; Mindell et al., 2012; Mosti et al., 2013; Salvesen, S., 2013; Wang et al., 2017; Richardson et al., 2018). Importantly, to reduce age-related physical deterioration, to cure aging is obviously the focus in the guidelines toward lowering the premature death rate and improving the quality of life in elderly.

Resistance training seems both directly and indirectly to be important for aerobic endurance improvements. Adaptations such as molecular, cardiovascular and metabolic, may improve work economy and endurance after ST (Salvesen, S., 2013). In addition, increased blood volume and blood flow to working muscle may increase the functional level. Moreover, greater tendon stiffness and enhanced neural activity may contribute to work economy and indirectly effect on health (Reeves et al., 2003; Salvesen, S., 2013). Resistance training seems to be important when weak individuals could be incapable of- or less motivated to perform physical activity, both in daily tasks and in extra exercises (Buchman et al., 2010; Milanovic et al., 2013; Brady et al., 2014; Fitten, L.J., 2015; Haraldstad et al., 2017; Tieland, et al., 2017). Haraldstad et al. (2017), on 60-81 years old men, have found small but significant positive correlations between improved muscle strength, and better physical and social function. Systematic resistance training was shown to be beneficial, and linked to augmented health-related quality of life expressed by physical and social function (Haraldstad et al., 2017). To understand that sustaining strength and muscle mass could be particularly beneficial for general and specific domains of quality of life may be essential when planning health promotion efforts targeting older adults.

Older adults are recommended to perform muscle-strengthening exercises to keep long-term health, reduce physical decay, maintain muscle mass, strength, and independence, improve gait patterns, balance adjustments, coordination and even work economy (Grimby, G., 1990; Persh et al., 2009; Romero-Arenas et al. 2013; Salvesen, S., 2013; Kanegusuku et al., 2015; Haraldstad et al., 2017; Marzetti et al., 2017; Wang et al., 2017). Furthermore, health and functional outcomes

in elderly are associated with maintaining cognition skills (Weinberg & Gould, 2015; Fernandes et al., 2017). Even small improvements in strength and mobility can be considered important for health and quality of life in older adults (Peterson et al., 2010). Because MST is characterized by high loads, the fear of potential injuries is always allocated. MST has, however, been shown to be feasible also in old (Fiatarone et al., 1990, Wang et al., 2017) with little risk of injuries (Unhjem et al., 2015). Nevertheless more research is needed to examine heavy-loads regimes in the elderly population.

2.3 The effect of age on maximal strength

With aging, the ability to generate maximal force declines annually (Larsson et al., 1979; Aniansson et al., 1986; Grimby, G., 1990; Frontera et al., 1991; Lindle et al., 1997; Daly et al., 2013). Reduced CSA, reduced cross-bridges force development due to impaired nervous function and thus impaired rate of Ca^{++} release, and limited ATP reformation are the major factors limiting strength with aging (Davies et al., 1986; Grimby, G., 1990; Aagaard et al., 2010; Clark et al., 2010; Frontera et al., 2010; Reid et al., 2013). Also a reduction in the number of fast twitch motor unit causes increased reaction time and increased movement time as well as reduced forced production during fast contractions (Lexell, J., 1995; Aagaard et al., 2010; Mau-Moeller et al., 2013; Reid et al., 2013; Unhjem et al., 2015, 2016; Wang et al., 2017).

A decrease in muscle performance occurs progressively, and both genders experience age-related losses in isometric, concentric and eccentric strength (Lindle et al., 1997). Larsson et al. (1979) have shown that the losses in absolute muscle strength starts already after the age of 40, with the rate 8-10% per 10 years. The most significant losses have been observed especially from the fifth decade, and then accelerates from the age of 65-70 years (Larsson et al., 1979; Frontera et al., 1991; Lindle et al., 1997; Daly et al., 2013). Moreover. After the seventh decade, loss in muscle strength may be greater than in muscle mass (Aniansson et al., 1986) due to increased nervous deterioration. Together with muscle strength reductions, loss of muscle power, has been observed. Reid et al. (2013) reported that muscle power impairments (2,9%/year) were associated with declination in the rate of neuromuscular activation.

2.3.1 Cross sectional area

According to Lindle et al. (1997) and Kallman et al. (1990), atrophy of whole muscle mass has been recognized at the whole muscle level in elderly. The general muscle mass atrophy occur by the lean mass and contractile properties reductions, and reduces cross-bridges force development (Mau-Moeller et al., 2013). Age-related decrease in muscle has been related to decreased physical activity (Taylor & Johnson, 2007, *Physiology of Exercise and Healthy Aging*), especially force-demanding or explosive actions (Grimby, G., 1990; Kortebein et al., 2007; Reid et al., 2013; Wall et al., 2013; Piirainen et al., 2014; Tieland et al., 2017). The main contributor to the muscle volume loss is therefore not surprisingly type II fibres atrophy in skeletal muscle (Grimby, G., 1990; Aagaard et al., 2010; Clark et al., 2010; Frontera et al., 2010; Reid et al., 2013).

The relationship between muscle strength and fat-free mass is an important predictor of muscle strength in elderly (Fiatarone et al., 1990). As lean mass is replaced with adipose tissue, and contractile properties are reduced, the muscle quality, expressed by force adjusted by fiber size, is impaired (Mau-Moeller et al., 2013). Azzabou et al. (2015) pointed out that intramuscular body fat percentage in sedentary older people increases with age, to the extent that mean fat ratio within the quadriceps femur muscle was 80% higher for older adults than young ones. According Reid et al. (2013), the intramuscular adipose tissue infiltration increased with advancing age, and correlated with the contraction velocity declination and loss in muscle power. However, Castillo et al. (2003) and, Azzabou et al. (2015) found lower fat percentage in physically active older adults.

2.3.2 Ca⁺⁺ release

Neuromuscular activation deteriorates with age (Haug & Eggers, 1991; Aagaard et al., 2010; Reid & Fielding, 2012; Tieland et al., 2017). Loss of motoneurons, reduced efferent motoneuron output and reduced neural drive to the muscle are associated with advancing age (Grimby, G., 1990; Aagaard et al., 2010; Mau-Moeller et al., 2013). Not only neuromuscular activation, but also the quality of the Ca⁺⁺ receptor-controlled channels decreases with advancing age (Payne et

al., 2009; Tieland et al., 2017). These impairments are exposed through reductions in contraction force and velocity (Reid et al., 2013). These alternations are also partly responsible for the extensive loss of type II motor unit compared to type I motor units (Grimby, G., 1990; Lexell, J., 1995; Zierath & Hawley, 2004; Mau-Moeller et al., 2013; Tieland et al., 2017).

2.3.3 ATP reformation

Metabolism plays a very important role in muscle fatigue. The falling rate of ATP resynthesis results in lesser force generated by contracting muscle during heavy exercises, as each myosin head needs to be loaded with an ATP unit in order to be able to create the sliding filament movement (Huxley, A.F., 1957; Bestel et al., 2001).

One important age-related alteration is seen within metabolic enzyme activities (Essen-Gustavsson & Borges, 1986; Preedy & Peters, 2002; Lanza et al., 2005; Feng et al., 2016). Both concentrations and the reformation activity of ATP have been observed to decrease with aging, first and foremost due to reduced velocity of anaerobic ATP reformation (Taylor & Johnson, 2007, *Physiology of Exercise and Healthy Aging*; Coen et al., 2013).

2.4 The effect of age on maximal strength training adaptations

Already in 1990, Fiatarone et al. observed reversibility of muscle weakness in nonagenarians aged 90-99 years old after 8 weeks of heavy-resistance training. Fiatarone et al. (1990) found improved muscle strength by 174%, muscle size and functional mobility. With 9 out of 10 subjects completing the training protocol, and all of the participants being able to perform exercises with a load 79,5% of 1RM, the feasibility even at these ages seemed good (Fiatarone et al., 1990). In a study by Unhjem et al. (2015), the applied training intervention of 8 weeks with heavy-resistance leg press resulted in 26% improvements in elderly in their 70s. In Wang et al. (2017), 8 weeks MST improved maximal strength, rate of force development, and work efficiency in older adults in their 70s to the level of sedentary young in their 20s.

2.4.1 Cross sectional area

Aging is associated with muscle mass loss, but heavy resistance strength training for 8-24 weeks can lead to marked gains in muscle cross sectional area in both genders at all ages (Fiatarone et al., 1990; Chilibeck et al., 1998; Campos et al., 2002; Romero-Arenas, 2013; Kanegusuku et al., 2015).

Previous studies have demonstrated that MST has a greater effect on type II motor units than less intensive strength training and therefore improves muscular strength the most (Campos et al., 2002; Schoenfeld et al., 2016; Richardson et al., 2018). Type II motor units are closely linked to balance adjustments and fall prevention (Hvid et al., 2010). In Wang et al. (2017), 26% restored muscle size and particularly 23% increased percentage of the total areal type II fibres was observed. A 32% higher prevalence of type II fibres was reported by Sharman et al. (2001) after MST in old. Also, Schoenfeld et al. (2016) found increased type II muscle fibres area after MST. According to Wilson et al. (2012), one mechanism behind a potential shift in muscle fiber types was that when properly challenged, “potentially”, type I may work as type II and conversely, type II may behave as type I. It is well established that the interconversions from Ix to Ia can occur with training (Staron et al., 1994; Sharman et al., 2001; Campos et al., 2002). If there is a shift from type I to type II after MST, or just a remodelling back to an original distribution after a neural sprouting effect with increasing age and decreasing activity is still debatable (Harridge, S.D., 2007; Wang et al., 2017).

2.4.2 Ca⁺⁺ release

Improved neural function seems to be essential for better coordination and muscle activation, and potential of muscular strength development also in old (Brentano et al., 2008). The association between strength training-induced gains in rate of force development (RFD) and increased maximal motoneuron firing frequency have been reported by Kamen & Knight (2004). Age-related neural deficiencies can to some extent be restored by MST (Unhjem et al., 2015, 2016), and this has proven to be clinically meaningful by improvements in functional mobility (Fiatarone et al., 1990).

Improved efferent drive to muscle due to the responses to MST in elderly subjects has been reported by several studies (Aagaard et al., 2002; Unhjem et al., 2015). As pointed out by Wang et al. (2017), MST-induced adaptations are mostly visible in RFD and neural improvements, and very little in muscle size gains. While MST has improved efferent drive, motoneuron firing frequency and motoneuron recruitment also in old, recreational moderate activity was not enough stimulus to maintain efferent drive (Unhjem et al., 2016). Also, Palmer et al. (2012) have shown alterations in white matter and putamen in the healthy adult brain, in the hemisphere controlling the trained leg after MST.

In Häkkinen et al. (2000), in old individuals (men in age 72 ± 3 years, women 67 ± 3 years), the strength gains were accompanied by increases in the maximal voluntary activation of the trained muscles. Häkkinen et al. (2000) also found increased number of active motor units, and increased their firing frequency.

Motor units has the ability to change after ST (Mrowczynski & Lochynski, 2014). Resistance training has evoked nervous system remodelling, also in elderly (Unhjem et al., 2015, 2016; Wang et al., 2017). However, in Patten et al. (2000), maximal MUDR was found to be lower in older adults than in young individuals. It is explained by the muscle contractile properties getting slower with aging (Doherty & Brown, 1997). Also, discharge rate has been found to decrease in elderly (Clamann, H.P., 1990). Although MST has proven to induce neural improvements also in old, improvements in activation of motor units seem to be somewhat smaller than in young (Unhjem et al., 2015). According to Unhjem et al. (2015), age-related impairments in efferent drive and firing frequency can be restored, but only to some extent, comparing to young individuals. It is therefore still not consensus as to how much MST can inflict muscular adaptations in older adults compared to young.

2.4.3 ATP reformation

MST may induce numerous metabolic adaptations. Firstly, maintaining tighter metabolic control, for example by matching ATP production with ATP hydrolysis (Conley et al., 2013; Layec et al., 2015). Secondly, enhance the resistance to fatigue during exercise of working muscle by

improving the velocity of muscle metabolism (Behm & St-Pierre, 1998; Sandstrup et al., 2016; Berg et al., 2018). Thirdly, MST may increase both levels and availability of the energy storages capacity in muscle for anaerobic ATP-generating pathways, for example enhancing the storage of phosphate in muscle (Tesh et al., 1986; Maglischo, E.W., 2003; Berg et al., 2018).

Muscular and metabolic performance decreases with age (Tieland et al., 2017), but can be improved with training (Lambert & Evans, 2005; Berg et al., 2018). Metabolic consequences of aging may determine the degree of training-related improvements (Grimby, G., 1990; Lambert & Evans, 2005). Older adults differ from young individuals in increased adipose tissue (Fiatarone et al., 1990; Mau-Moeller et al., 2013; Maden-Wilkinson et al., 2015), and muscular performance properties (Dionne et al., 2004; Lambert & Evans, 2005). Although MST has proven to evoke metabolic improvements also in old, do these adaptations apply to the same extent as in young?

Dionne et al. (2004) also supported that age-related changes in metabolism was dependent on age. In contrast, in Lambert & Evans (2005) it was concluded that in older adults both mitochondrial density and oxidative enzymes were increased upon resistance training, but decreased in young individuals. However, these alterations may be linked to the initial training status, which was greater in younger ones.

Whether there is a difference between young and old in MST metabolic adaptations, stays unclear because of lack of research involving very old subjects in heavy loads ST.

3.0 Methods

The research question: *Does age affect strength adaptations to MST?* was addressed by an intervention study conducted at USN. The sub research question: *To what extent is chronologic age and or a more sedentary life-style influencing on reduced muscular strength in elderly?* Was addressed by a literature review supporting the intervention study.

Methods presented in this thesis have thus been applied from the study «Effekt av maksimal styrketrening for voksne i ulike aldersgrupper» at the University of South-Eastern Norway, campus Bø. This study was a controlled training intervention with pre-test - post-test design.

The participants were recruited by invitation and advertisements in the local community of Telemark.

To follow ethical regulations, the study was approved by, and registered in NSD (Norsk Senter for Forskningsdata), and USN (University of South-Eastern Norway). By application to the Regional Medical Ethics Committee (REK), it was decided by REK that the study did not constitute endorsement to the Norwegian health legislation and was therefore not considered by REK.

3.1 Participants

A total of 103 healthy males and females in the age of 20 to 77 years signed up for the study. Of these, 76 completed baseline testing. The number of completers throughout the study were 49 subjects.

A flow-chart of the participation is presented in figure 1, and inclusion- and exclusion criteria are presented in table 1.

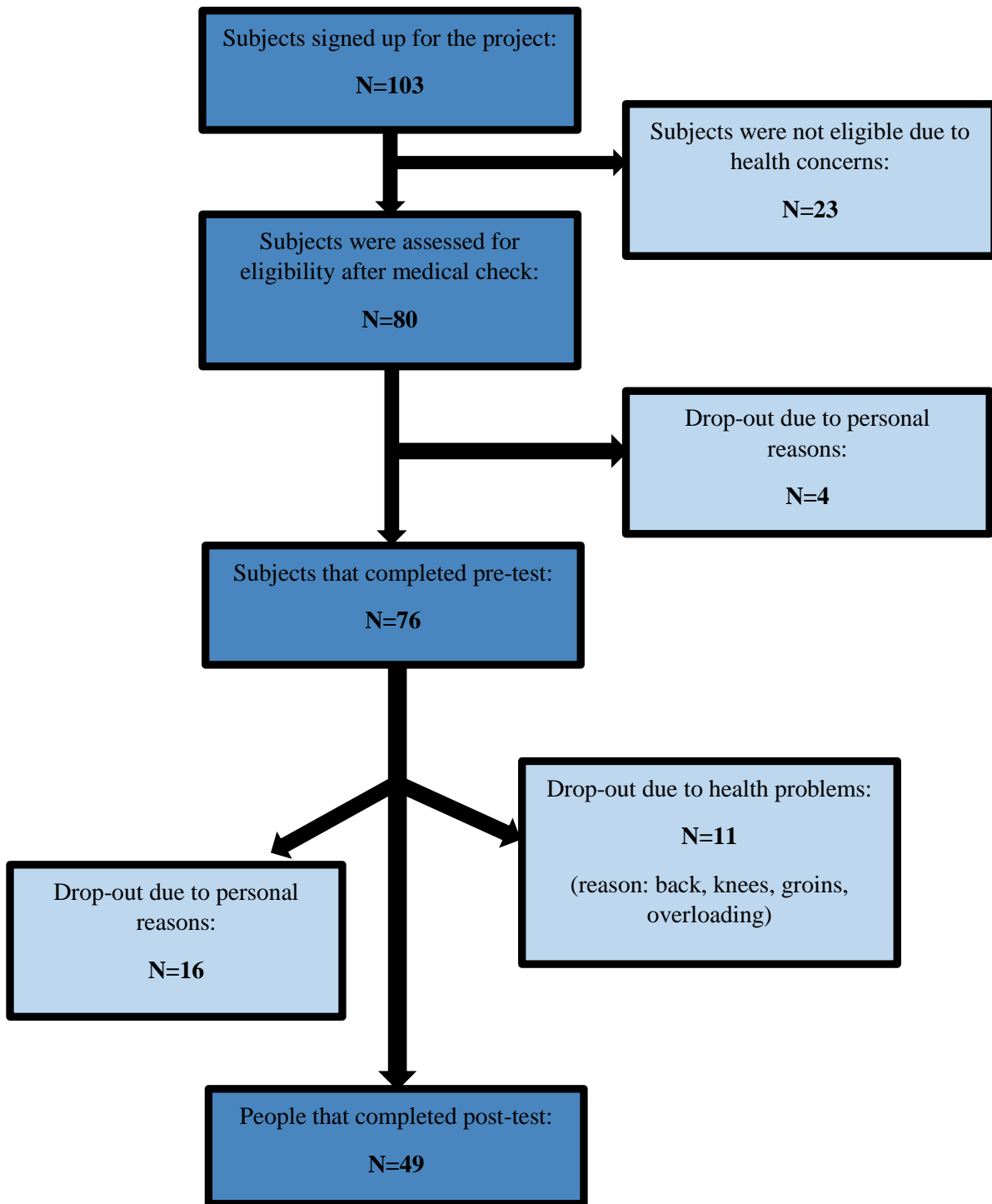


Figure 1: Flow-chart of participation

N, number of subjects.

All subjects who signed up for the study underwent a medical examination prior to baseline testing. This examination included body weight, height, BMI, blood pressure, history of serious health problems in the family, actual medication, social- and work-related issues. Prior the study, a survey of physical activity and general functional assessment were conducted. Participants free of health problems were approved, to take part in the study.

Table 1. Inclusion and exclusion criteria for participating in the study

Inclusion:	Exclusion:
20 – 80 years old	under 20 years old
healthy individuals (approved by physician)	Contraindications for hard physical activity. Sick and/or injured during the last week prior to the test.
Signed self-declaration	Sick and/or injured for two weeks during the last month prior to the test. Less than 70% of all the training sessions completed, or a whole week without a session.

In order to compare age-groups improvements, all age-groups had to be matched for relative 1RM, i.e. corrected for age, body weight (BW) and gender. 1RM relative to age, BW and gender is presented in table 2.

Table 2. Baseline characteristics

age-group	age (years)	gender (M/F)	BW (kg)	1RM (kg)	1RM corr (kg·kg ^{-0.67})
20-29	25.6±2.8	3/7	73.4±8.9	224.5±53.3*	18.1±4.7
30-39	33.9±2.8	7/2	83.5±11.8	362.2±135.3#	20.8±4.9
49-49	44.2±3.2	5/7	74.4±12.5	255.8±86.9*	20.5±4.3
50-59	53.5±3.0	4/4	80.8±15.1	240.6±77.6**	18.3±3.4
60+	70.3±4.3	3/7	76.3±12.2	191.0±50.8**#	19.4±5.5

Data presented as mean ± SD. BW, body weight. RM, repetition maximum. Kg, kilogram. M, male. F, female. Corr, corrected for age, gender and BW. *p<0.05 different from 30-39, **p<0.01 different from 30-39, # p<0.05 different from 40-49.

3.2 Testing

The participants underwent a series of tests as a part of the study «Effekt av maksimal styrketrening for voksne i ulike aldersgrupper». Only the tests relevant for the present master thesis are described here.

All physical tests were performed on the same day for each participant. Equipment used to perform these tests included: leg press (OPS161, Vertex, USA), software Muscledlab DSU (Ergotest Innovation AS, 3937 Porsgrunn, Norway), body weight (Tefal sensitive computer PP 6010, France), skinfold caliper (Saehan Medical, SH5020, Korea) and measuring tape.

Subjects performed the same tests twice, pre and post the eight weeks intervention.

First, all essential anthropometrical measurements (height, weight, waist volume, hip volume and percentage body fat) were conducted, and performed by the same trained person from the research group. BMI was calculated as body weight divided by height in meters raised to the power of two. Waistline and hips measurements were done by use of measuring tape. Fat percentage was calculated from measurements using skinfold caliper in 5 points: triceps, biceps, chest, suprailiac, abdomen and thigh.

After anthropometric tests, the participants warmed up by cycling on a stationary bike or running on a treadmill for 10 minutes at moderate intensity, and was then acquainted to the leg press machine. They then performed four sets with numerous repetitions and gradually heavier. Three to five minutes rest were given between each set. First set consisted of 10 repetitions of a light load at ~50% of predicted 1RM. Then 5 repetitions of ~60% load of predicted 1RM, and in the third set, they performed three repetitions of ~70% load of predicted 1RM. After this, one repetition of ~80% load of predicted 1RM was performed. Finally, one and one repetition with increasing loads until a failure were performed in order to reach and control 1RM.

3.3 Training

During the eight weeks intervention, participants conducted 4*4 RM in leg press, performed 3 times a week. Participation of minimum 70% of scheduled training was required in order to complete the intervention. Training sessions were assisted by trained members of the research group, and monitored. In addition, all habitual physical activity was logged by the participants in a standardised scheme.

Each intervention session started with a warm-up of 10 minutes at 60-70% HR_{max} performed as running on the treadmill or cycling on the stationary bike. Warm up was continued by performing leg press on the machine by respectively: 10 repetitions of 50% load of predicted 1RM and after 3-5 minutes rest period and 3 repetitions of 75% of predicted 1RM, also followed by 3-5 minutes rest. Main training consisted of 4 series of 4 RM with 3-5 minutes rest periods between sets. If a subject managed to do five repetitions in a set, the weight load was increased by 5 kg in the following set.

3.4 Statistics

All statistical analyses, tables and graphic figures were performed by using Microsoft Excel (2016) and SPSS, version 25 (Statistical Package for Social Sciences, IBM, USA). All results were presented as mean \pm standard deviation (SD). In order to use parametric statistics, the

material was tested for normality by use of QQ-plot and Kolmogorov-Smirnov test in age, and gender corrected 1RM leg press at baseline. The material was found to be normally distributed. A general linear model (GLM) with Tukey post hoc tests was used to evaluate possible differences in improvements between age-groups. A Pearson bivariate correlation test was used to assess if baseline 1RM correlated with 1RM improvements. The significance level was set to $P < 0.05$ in two-tailed tests.

4.0 Results

All participants improved 1RM (table 3). As a total, 1RM improved by 24 % (23.8 ± 4.7 %; $p < 0.05$). No significant differences were apparent between age-groups (Table 3). Men and women had the same level of improvements in 1RM.

Table 3. Results by age-groups (N=49)

	20-29 (N=10)	30-39 (N=9)	40-49 (N=12)	50-59 (N=8)	60+ (N=10)
Age (years)	25.6 \pm 2.8	33.9 \pm 2.8	44.2 \pm 3.2	53.5 \pm 3.0	70.3 \pm 4.3
BW baseline (kg)	73.4 \pm 8.9	83.5 \pm 11.8	74.4 \pm 12.5	80.8 \pm 15.1	76.3 \pm 12.2
Δ BW (%)	0.4 \pm 1.2	-0.4 \pm 2.7	1.8 \pm 3.0	0.7 \pm 0.9	-0.9 \pm 1.8
1RM baseline (kg)	224.5 \pm 53.3	362.2 \pm 135.3	255.8 \pm 86.9	240.6 \pm 77.6	191.0 \pm 50.8
Δ 1RM (%)	19.5 \pm 7.4	25.5 \pm 15.0	30.9 \pm 19.2	20.2 \pm 9.3	22.9 \pm 13.3
Δ 1RM (kg)	42.5 \pm 15.1	81.7 \pm 34.8*	77.3.5 \pm 43.4	50.0 \pm 29.2	40.5 \pm 16.4

Data presented as mean \pm SD. BW, body weight. RM, repetition maximum. Kg, kilogram. N, number of individuals. *($p < 0.05$) larger improvement than 60+

Baseline 1RM did not correlate with 1RM improvements ($R=0.026$, $p=0.86$).

5.0 Discussion

The main finding in this thesis was that all age-groups improved 1RM leg press after eight weeks of MST. There were no differences in 1RM improvement between age-groups or genders, nor did initial training status affect the improvements. At baseline, 1RM was lower with higher age from 30-39 years and upwards.

5.1 Age differences in 1RM at baseline

Absolute 1RM was lowest in the 60+ group. Participants in the oldest age-group exhibited in average $191,0 \pm 50,8$ 1RM pre-test, while the whole study population showed $254,8 \pm 64,7$ 1RM in pre-test measurements. The oldest group showed about 30% lower muscle strength than all younger groups together in average at baseline. It is noteworthy that the 30-39 group was actually stronger than the 20-29 group at baseline, but this may be partly due to a higher number of female participants in the youngest group. When corrected for age, gender and BW, there were no differences in baseline 1RM.

The finding that 1RM decreased with increasing age at baseline is in accordance with several previous studies (Larsson et al., 1979; Grimby, G., 1990; Frontera et al., 1991; Lindle et al., 1997; Tieland et al., 2017). Also, in accordance with the present study, Daly et al. (2013) found that the most pronounced drop started around the fifth decade, and then accelerated from the age of 65-70 years. The control calculation in the present study, with the different age-groups corrected for age, gender and BW at baseline, was important both to compare baseline values, and to compare adaptations to the MST intervention. The importance of having matched groups regarding training status or performance levels have been demonstrated by the results from Unhjem et al. (2016). Unhjem et al. (2016) reported that sedentary old performed 106 ± 11 kg in leg press, whereas recreationally active old performed 128 ± 15 kg, young performed 147 ± 22 kg, and old athletes as much as 185 ± 32 kg. Compared to previous studies (Ahtiainen et al., 2003; Reeves et al., 2004; Fimland et al., 2009b; Botero et al., 2013; Kanegusuku et al., 2015; Unhjem et al., 2015; Wang et al., 2017), the cohorts in the present study seemed to have similar or

slightly above average 1RM at baseline, although direct comparisons are difficult due to different leg press equipment in the different studies.

Previous studies have indicated several factors that may explain lower values of 1RM in older adults compared to young. Body composition changes to less relative muscle mass (Harridge, S.D., 1996; Vidt et al., 2012; Mau-Moeller et al., 2013). CSA is reduced especially in type II fibres, and neuromuscular activation gets worse (Reid et al., 2013). In addition, slowed down loading of SR with Ca⁺⁺ release decreases muscle force, causing worse quality of the Ca⁺⁺ receptor-controlled channels (Payne et al., 2009; Tieland et al. 2017). Last but not least, a decrease in the rate of ATP resynthesis limits the muscle to contract, resulting in lower level of maximal strength in older subjects when compared with younger ones (Huxley, A.F., 1957; Bestel et al., 2001; Coen et al., 2013).

5.2 The same improvements in 1RM adaptations across different age

The mean improvement in 1RM was 24%. In relative terms (%), there was no significant difference between age-groups. In absolute terms (kg), the only difference in improvement was between the 30-39 and the 60+ group, in favour of the 30-39 group (table 3). However, this level of muscular improvement is not always similar to those previously reported (Ahtiainen et al., 2003; Salvesen, S., 2013; Wang et al., 2017). Also, there was no difference observed between males or females in the present study, which is in accordance with previous studies (Fiatarone et al., 1990; Häkkinen et al., 2000, 2001).

The magnitude of improvements in the present study is somewhat smaller than in previous studies, like the 42% in young (Campos et al., 2002; Ahtiainen et al., 2003; Fimland et al., 2009b) and 45% in old (Reeves et al., 2004; Brentano et al., 2008; Persh et al., 2009; Botero et al., 2013; Salvesen, S., 2013; Kanegusuku et al., 2015; Unhjem et al., 2015; Haraldstad et al., 2017; Wang et al., 2017). It is, however, challenging to find comparable results for the in-depth discussion, because, regardless of many investigations on resistance training in elderly, little is still known about maximal loads (80-95% of 1RM) in this age-group.

In a previous study, Ahtiainen et al. (2003) found 1RM to improve by 19% in non-strength trained but active men, and 7% in strength athletes. This is in contrast to the present study where baseline 1RM did not influence the improvements.

Although bodyweight did not change in any age-group in the present study, the improvements are probably to some extent due to muscle hypertrophy. According to Rogers & Evans (1993), progressive resistive training in older individuals results in muscle hypertrophy accompanying increased strength. This was also seen in the work of Unhjem et al. (2015), with $4,4 \pm 3,5\%$ hypertrophy after resistance training. In older subjects, MST has also been shown to be an effective strategy to gain both structural and neural adaptations. Findings of Kosek et al. (2006) and Patten et al. (2000) revealed that older adults increased muscle volumes to a comparable level as active young. Although partly due to hypertrophy, the 1RM improvements from MST in the present study was probably also due to neural adaptations (Häkkinen et al., 2000; Brentano et al., 2008). Greater activation, increasing motor unit recruitment, and increased firing rate of the active motor units has been shown after MST (Aagaard et al., 2002; Brentano et al., 2008). Also, changes in agonist vs antagonist activation may have occurred after the MST intervention (Reeves et al., 2004). As a result of hypertrophy, fat-free mass may have increased (Fiatarone et al., 1980; Folland & Williams, 2007; Unhjem et al., 2015). In previous studies, alternations in myosin heavy-chain isoforms have been altered, converting type IIB to type IIA (Sharman et al., 2001). This may have occurred in the present study as well. Wang et al. (2017) found that in old, to some extent, type I motor units were converted towards type II. The fact that old at baseline in Wang et al. (2017) showed a less percentage of type II motor units than young may indicate that it may be also lifestyle, not only age, that lead to muscular impairments. Finally, MST may have improved concentrations of phosphagen in the present study, and thus the metabolic process to reform ATP to a quick enough rate (Taylor & Johnson, 2007, *Physiology of Exercise and Healthy Aging*).

5.3 Methodological and ethical considerations

5.3.1 Methodological considerations

The test protocols in the present study were by use of standardized tests previously used at the USN lab. To address the research questions, data was anchored to specific variables, pictured by the numbers, and the existing literature was reviewed. Criteria such as: validity, accuracy, quality control and falsifiability, have been attained throughout the study (Friis & Vaglum, 1999; Graton & Jones, 2004; Thomas et al., 2005). No qualitative data was included, and thus nuances such as feelings and reflections presented in logs about the mood and general being have not been presented as results. As a result of this, we know less about the subjective experiences from the intervention.

Test pros and limitations

The first assessments of 1RM was always too low, resulting in several attempts to reach 1RM baseline. This may have led to a slightly more fatigued state and thus impaired 1RM baseline to some extent. In accordance with the participants, two to three subjects could be tested at the same test bulk. Although professionally carried out, this could make the test situation more affected by stress, chaos and overtime rest periods. Also, technical issues as position at the turn-over point in the leg press may have contributed to potential biases.

Training pros and limitations

MST was employed to maximize muscular strength, as 1RM was the main outcome. Even though it may be beneficial for functionality concerns in elderly, gains in muscle volumes were not the subject of the interest in this thesis. For safety reasons, participants were instructed to rest properly and trained to master the technique when the experiment was carried over time. For performance outcomes, principles and guidelines for MST were followed. Dynamic repetitions with both CON and ECC were applied as contributing in larger improvements than isometric muscle action due to 1 RM trainability (Kraemer & Ratamess, 2004; Friedmann-Bette et al., 2010). In contrast to recommendations of American College of Sports Medicine (2002), high-

resistance/low-repetitions training was chosen. Numerous studies (Campos et al., 2002; Vincent and Braith, 2002; Beneka et al., 2005; Brentano et al., 2008; Salvesen, S., 2013; Schoenfeld et al., 2016; Wang et al., 2017) admit that MST shows the greatest improvements in 1RM and power, comparing to less effective - circuit weighted training. Load, volume and rest intervals were thus established to maximize strength outcomes. Following De Salles et al. (2009), 3-5 minutes rest intervals are best from a psychological and physiological standpoint.

In untrained and elderly, it is first of all about the safety. Favouring leg press over similar exercises for its safety concerns (making the program beneficial and reducing risk factors), seems to be still efficient when included in muscle strength gains-orientated MST. However, in real life, in not previously strength-trained, the current training intervention may have been too challenging to complete 8 weeks. Reflecting on the observed drop-out from the intervention, the applied regime may have some drawbacks, and may not be suitable for all. At the best, this intervention was effective in improving 1RM in all completers, but it says little about why some did not complete the intervention.

According to Ahtiainen et al. (2003), previous strength training experience might affect relative gains, greater for the not-trained before, as the improvements' capacity exists. However in the present study, no correlation was obtained between baseline 1RM and MST adaptations. Also, according to Brentano et al. (2008), men and women may adapt differently to training dependent on hormonal status etc. However, in the current study, no gender differences were observed in MST adaptations. Thus it should not be a disadvantage that more females were included in groups 20-29 y/o (7 women, 3 men), and 60+ (7 women, 3 men), and then few female in 30-39 y/o (2 female, 7 men) when comparing to more equally distributed: 40-49 years old (7 women, 5 men) and 50-59 y/o (4 women, 4 men).

5.3.2 Ethical considerations

Prior to the tests and intervention, participants were fully informed about the purpose and procedures of the intervention, also about personal advantages and potential risk that might occur. Subjects agreed to take part in the research voluntary and signed the consent to contribute

in the research. It was stated that they had the right to leave the project at all times without the need for any given reasons. All obtained data and samples were anonymised in the publication, and there were only few authorised persons that had access to the name to number code-list. All participants also underwent a medical examination by the project's physician before participation. For the safety concerns, a leg press apparatus was chosen as opposed to the more frequently used free squats. This was due to that older participants may have some problems with keeping balance and handle proper technique while training with the free weights or using the Smith machine. In spite of the safety precautions, 11 participants who dropped out due to health problems may seem a lot for a total of 76 who had completed pre-test. It should however be noted that some of the problems were old underlying issues. All the same the drop-out rate may imply that MST in leg press is not applicable to all, although high-resistance strength training has been reported as feasible and not likely to result in injuries (Fiatarone et al., 1990; Wang et al., 2017).

5.4 Practical applications

Results from the present study suggest that MST, in spite of some health-related withdrawals, is a feasible and effective method to improve muscular strength at all ages and both genders. All subjects who accomplished the required amount of training sessions and completed post-test, improved 1RM. In practice, MST may be recommended for all age-groups.

The finding of the present study that age did not influence response to strength training in relative terms (%), could be a motivating factor for those wanting to maintain or improve general physical health and fitness. MST may be thus one strategy to counterattack age-related physical and social deteriorations.

In the present study neither age nor gender correlated with strength improvements. Thus, it is hard to state what the determining factors for strength adaptations upon MST are. Further studies within genetics are needed to develop broader view over possible components regulating strength adaptations, as are studies with both lighter and heavier weekly training loads. Such knowledge may be of special importance when designing health promoting strategies and for targeting

groups of higher risk due to health issues. Also, more studies are needed in order to move towards a generalization regarding the trainability of MST in different age-groups.

6.0 Conclusion

The present study revealed that regardless of age, gender or training history, maximal muscular strength was improved after MST. MST could therefore be a relevant and efficient interventional strategy to promote health and functionality in elderly.

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Appendices

Appendix 1



Egenerklæringsskjema om helse

Etternavn:	Fornavn:	Født:
Høyde:	Vekt:	Lag / forening / studie:
Telefon:	Telefon kontaktperson:	

Siden det er første gang du testes ved idrettsfysiologisk testlaboratorium, ber vi deg lese nøye igjennom alle spørsmålene på denne listen. Kryss av enten JA eller NEI for hvert spørsmål. Dette er viktig i forhold til hvordan vi gjennomfører testingen av deg.

	JA	NEI	
1	<input type="checkbox"/>	<input type="checkbox"/>	Kjenner du til at du har en hjertesykdom?
2	<input type="checkbox"/>	<input type="checkbox"/>	Hender det at du får brystmerter i hvile eller i forbindelse med fysisk aktivitet?
3	<input type="checkbox"/>	<input type="checkbox"/>	Kjenner du til at du har høyt blodtrykk?
4	<input type="checkbox"/>	<input type="checkbox"/>	Bruker du for tiden medisiner for høyt blodtrykk eller hjertesykdom (f.eks vanndrivende tabletter?)
5	<input type="checkbox"/>	<input type="checkbox"/>	Røyker du?
6	<input type="checkbox"/>	<input type="checkbox"/>	Bruker du snus?
6	<input type="checkbox"/>	<input type="checkbox"/>	Kjenner du til om du har høyt kolesterolnivå i blodet?
7	<input type="checkbox"/>	<input type="checkbox"/>	Har du besvint siste 6 måneder i forbindelse med fysisk aktivitet?
8	<input type="checkbox"/>	<input type="checkbox"/>	Hender det at du mister balansen på grunn av svimmelhet?
9	<input type="checkbox"/>	<input type="checkbox"/>	Har du sukkersyke?
10	<input type="checkbox"/>	<input type="checkbox"/>	Er du fysisk inaktiv og har et stillesittende arbeid?
11	<input type="checkbox"/>	<input type="checkbox"/>	Bruker medisiner fast – mot:
12	<input type="checkbox"/>	<input type="checkbox"/>	Har du eller har du hatt en luftveisinfeksjon i løpet av siste uke?

Jeg / vi har også lest i gjennom forberedelseskjema for testen, og er inneforstått med hvordan testen foregår.

.....
Dato Underskrift

.....
Dato Underskrift av foresatt dersom testpersonen er under 18 år

Self-declaration questionnaire.

Appendix 2

Forespørsel om å deltakelse i forskningsprosjektet:

Effekt av maksimal styrketrening for voksne i ulike aldersgrupper

Bakgrunn og hensikt

Dette er en forespørsel til deg om å delta i et forskningsprosjekt for å se effekten av maksimal styrketrening for voksne i ulike aldersgrupper. Forskningsprosjektet vil bli gjennomført på idrettsfysiologisk testlaboratorium ved Høgskolen i Telemark, Bø.

Hva innebærer prosjektet?

Alle som melder seg frivillig til å delta i dette forskningsprosjektet må fylle ut egenerklæringsskjema om helse og godkjennes av prosjektets medisinske ansvarlig før de blir inkludert i prosjektet. Det vil bli gjennomført en medisinsk undersøkelse, det kan være aktuelt at medisinsk ansvarlig tar kontakt med fastlege for utfyllende opplysninger.

Egenerklæringsskjemaet inneholder blant annet spørsmål om vekt, fødselsdato, sykdommer for deg (se vedlegg). Dette vil skje før pretest. Deltakerne må også i løpet av siste uke før både pre-test og post-test innom lab på nærmeste sykehus eller legesenter for å ta blodprøver til genanalyser. Disse prøvene vil bli oppbevart på en lab på Høgskolen i Telemark, Bø. Det er kun tre prosjektmedarbeidere som har tilgang til disse prøvene. Prøvene vil være låst inne og ligge separert fra kodenøkkel. Prøvene blir destruert fortløpende etter analysen er blitt gjort. Det vil ikke gis tilbakemelding på resultat, hvis ikke det mot formodning kommer resultater med diagnostisk eller helsemessig relevans. Det er svært liten sjanse for dette på grunn av det utvalget av gener vi ser på og man kan reservere seg for å få denne informasjonen. Disse prøvene vil også bli brukt i prosjektet «Gener, miljø og/eller deltagelse i organisert idrett – faktorer som forklarer fysisk aktivitet». Dette prosjektet vil det komme mer informasjon om på et senere tidspunkt.

Ved pre- og posttest møter deltakerne på idrettsfysiologisk testlaboratorium ved Høgskolen i Telemark, Bø. Her gjøres først antropometriske målinger (høyde, vekt, midjemål, hoftemål og fettprosent med kaliper). Så går vi over til de fysiske testene. Disse testene gjennomføres på følgende måte:

1. Oppvarming: 10 minutter på tredemølle, sykkel eller romaskin (estimert 50-70 % av Hfmax).

2. Testing av vertikal spenst:
 - a. Gjennomfører tre squat jump, hopp uten svikt fra 90 grader i kneleddet med hoftefeste. 3-5 minutter hvile mellom squat jump og counter movement jump.
 - b. Gjennomfører tre counter movement jump, hopp med svikt og hoftefeste.
3. Testing av maksimal styrke og effekt:
 - a. Gjennomfører en serie med 10 repetisjoner med belastning på antatt 50 % av 1 repetisjon maksimum (1 RM). 3-5 minutters hvile til neste serie.
 - b. Øker belastningen til antatt 60 % av 1 RM og gjennomfører 5 repetisjoner. 3-5 minutters hvile til neste serie.
 - c. Øker belastningen til antatt 70 % av 1 RM og gjennomfører 3 repetisjoner. 3-5 minutters hvile til neste serie.
 - d. Øker belastningen til antatt 80 % av 1 RM og gjennomfører 1 repetisjon. 3-5 minutters hvile til neste serie.
 - e. Etter dette økes belastningen med 2,5-5 kg per løft, 5 min hvile mellom hvert løft inntil 1RM er nådd.

Treningen vil være maksimal styrketrening og vil foregå 3 dager i uka i 8 uker. Program og veiledning vil bli gitt ved pretest og underveis i prosjektperioden.

Mulige fordeler og ulemper

Fordelene med å delta i dette prosjektet er blant annet at personen vil høyst sannsynlig bli sterkere og øke sin evne til raskere å oppnå maksimal kraftutvikling og balanse. Økt kunnskap om trening og virkning på kroppen. Alle deltakerne vil få kyndig veiledning under trening og testing.

Ulemper er at deltakerne må sette av tid til treningsintervensjonen og det kan oppleves som fysisk slitsomt. Selv om deltakerne er undersøkt av lege, må testpersonene likevel akseptere en hvis risiko for at sykdom og/eller at skade kan oppstå som følge av deltakelse i forskningsprosjektet.

Hva skjer med prøvene og informasjonen om deg?

Alle opplysninger og prøvene vil bli anonymisert i publikasjon. Denne anonymisering vil skje senest en uke etter pre-test. En kode knytter deg til dine opplysninger og prøver gjennom en navneliste. Det er kun noen få av de som har ansvar for prosjektet som har tilgang til navnelisten og som kan finne tilbake til deg. Disse dataene vil bli låst inn i egnet skap og anonymisert etter prosjektet er avsluttet i desember 2017. Blodprøver vil bli destruert fortløpende etter analysen er blitt gjort.

Frivillig deltakelse

Det er frivillig å delta i prosjektet. Deltakerne kan når som helst og uten å oppgi grunn trekke seg fra prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen. Det er også valgfritt om man ønsker å delta i prosjektet «Gener, miljø og/eller deltagelse i organisert idrett – faktorer som forklarer fysisk aktivitet».

Ved spørsmål vedrørende prosjektet kan du kontakte prosjektleder Hans Torvild Kittilsen på 97105280 og e-post: hans.t.kittilsen@hit.no

Samtykke til deltakelse i prosjektet

Jeg er villig til å delta i studien

----- (Signert av
prosjektdeltaker, dato)

Jeg bekrefter å ha gitt informasjon om studien

----- (Signert,
rolle i studien, dato)

Appendix 3



Høgskolen i Telemark Avdeling for allmennvitenskapelige fag

Effekt av maksimal styrketrening for voksne i ulike aldersgrupper

Treningsprotokoll: maksimal styrketrening

Alle deltakerne gjennomfører 4 x 4 RM i beinpress (beinpress) tre ganger i uken i åtte uker.

Det vil være treningsveileder tilstede under 50 % av treningsøktene og ellers ved behov.

Trening:

Maksimal styrketrening: Tre Økter i uken i 8 uker, med krav om 70% deltakelse.

1. Oppvarming på ca 50-70% av Hfmax i 10 minutter.
2. Beinpress med belastning tilsvarende 50 % av 1 RM, gjennomfører 10 repetisjoner. 35 minutters hvile til neste serie.
3. Beinpress med belastning tilsvarende 75 % av 1 RM, gjennomfører 3 repetisjoner. 3-5 minutters hvile til neste serie.
4. 4 serier x 4 RM, mellom hver av seriene 3-5 minutters hvile.

Kontrollgruppe:

Det vil ikke bli benyttet en egen kontrollgruppe, men deltakerne vil i praksis utgjøre seks grupper basert på alder (20-29, 30-39, 40-49, 50-59, 60-69 og 70+ år).

Testprotokoll:

De fysiske testene gjennomføres på en dag (både pre og postintervensjon). Pretesten gjennomføres etter en til tre tilvenningsøkter som skal sikre tilfredsstillende teknikk under utførelse av øvelsene.

Posttest gjennomføres etter minimum en hviledag etter siste treningsøkt.

Disse prosedyrene er brukt i tidligere publiserte studier ved Høgskolen i Telemark (Støren et al., 2008; Sunde et al., 2010, Støren et al., 2011, Støren et al., 2013). Deltakerne testes av ansatte ved laboratoriet. Alle ansatte har gjennomgått og bestått HLR — kurs samt bruk av halv-automatisk hjertestarter. Det

finnes hjertestarter tilgjengelig ved laboratoriet. Alle ansatte har idrettsutdanning med idrettsfysiologi og har lang erfaring med arbeid på testlab.

Selve testing gjennomføres slik:

1. Deltakerne møter på idrettsfysiologisk testlaboratorium ved Høgskolen i Telemark, BØ. Her gjøres først antropometriske målinger (høyde, vekt, midjemål, hoftemål og fettprosent med kaliper).
2. Oppvarming: 10 minutter på tredemølle, sykkel eller romaskin (estimert 50-70 % av maksimal hjerterefrekvens).
3. Testing av vertikal spenst:
 - Gjennomfører tre squat jump, hopp uten svikt fra 90 grader i kneleddet med hoftefeste. 3-5 minutter hvile mellom squat jump og counter movement jump.
 - Gjennomfører tre counter movement jump, hopp med svikt og hoftefeste.
4. Testing av maksimal styrke og effekt:
 - Gjennomfører en serie med 10 repetisjoner med belastning på antatt 50 % av 1 RM. 3-5 minutters hvile til neste serie.
 - Øker belastningen til antatt 60 % av 1 RM og gjennomfører 5 repetisjoner. 3-5 minutters hvile til neste serie.
 - Øker belastningen til antatt 70 % av 1 RM og gjennomfører 3 repetisjoner. 3-5 minutters hvile til neste serie.
 - Øker belastningen til antatt 80 % av 1 RM og gjennomfører 1 repetisjon. 3-5 minutters hvile til neste serie.
 - Etter dette økes belastningen med 2,5-5 kg per løft, 5 min hvile mellom hvert løft inntil 1RM er nådd.

Deltakerne må også i løpet av siste uke før både pre-test og post-test innom lab på nærmeste sykehus eller legesenter for å ta følgende blodprøver til genanalyser. Dessuten må deltakerne fylle ut egenerklæringsskjema om helse og godkjennes av prosjektets medisinske ansvarlig før pretest.

For at testen skal bli mest mulig vellykket og så sikker som mulig, er forberedelsene viktige.

Deltakerne bør:

- Føle seg friske og skadefrie

- Ikke ha fått påvist sykdom eller skade som kan utgjøre en helserisiko ved større fysisk belastning
- Ikke hatt sykdom med feber eller luftveisinfeksjon siste tre døgn (helst siste uke)
- Ikke trene hardt de siste 24t
- Ikke drikke alkohol siste 24t
- Ikke innta tobakk eller koffein siste 4t
- Ikke spise siste 2t
- Ikke drikke annet enn vann siste 2t
- Føle seg mest mulig utvilt til testen
- Ellers leve mest mulig som normalt før testen

Blodprøver:

Blodprøvene tas rett før og rett etter treningsperiode ved hjelp av standard blodprøveprosedyre ved et laboratorium tilknyttet deltakerens nærmeste legesenter.

Rekvisisjon blir gitt av prosjektets lege, Bård I. Freberg.

Antropometriske målinger:

BMI blir beregnet ut fra kroppsvekt (kg) delt på høyde opphøyd i andre (m²). Midjemål og hoftemål måles ved hjelp av målebånd. Fettprosent måles ved hjelp av 5 hudfoldmålinger (triceps, chest, abdomen, suprailiac, thigh),

Apparatur:

Idrettsfysiologisk laboratorium ved Høgskolen i Sør-Øst Norge, avdeling BØ benytter følgende apparatur i studiet; Beinpress, OPS161 Interchangeable leg press, Vertex, USA Musclelab DSU, Ergotest Innovation AS, 3937 Porsgrunn, Norway Vekt: Tefal sensitive computer PP 6010, France. Fettprosent: Saehan Medical Skinfold Caliper, SH5020, Korea.

Eksklusjonskriterier for deltakelse:

Inklusjonskriterier: For å kunne delta må du:

- Være frisk og over 20 år.
- Fulle ut og undertegne et egenerklæringsskjema for helse
- Godkjent av prosjektets medisinske ansvarlig

Eksklusjonskriterier:

Du kan ikke delta dersom du:

- Viser kontraindikasjoner for hard fysisk aktivitet (dvs at dette er helsemessig ugunstig for deg).
- Har vært syk i mer enn 2 uker sammenhengende den siste måneden før teststart
- Har vært syk den siste uken før teststart.

Som deltaker blir du tatt ut av studiet hvis:

- Du gjennomfører mindre en 70% av treningsøktene
- Blir syk i mer enn en uke sammenhengende under treningsperioden

Eksklusjon vedrørende deltakelse i prosjektet baserer seg på en helhetsvurdering foretatt av prosjektets lege Bård I. Freberg. Helhetsvurderingen baserer seg i sin tur på opplysninger og prøveresultater innhentet på følgende måte:

1. Opplysninger gitt av forsøkspersonen gjennom samtale med lege og avkrysning på egenerklæringsskjema for helse ved idrettsfysiologisk testlaboratorium, Høgskolen i Telemark (skjema vedlagt). Egenerklæringsskjemaet er utviklet i samarbeid med Kåre Ulevåg, lege og spesialist i fysikalsk medisin og idrettsmedisin ved Tvedestrand idrettsmedisin.

2. Opplysninger innhentet fra forsøkspersonens fastlege (etter forsøkspersonens samtykke), og som inneholder informasjon om:

- Vekt, høyde, BMI
- Blodtrykk
- Kronisk alvorlig sykdom i familien
- Opplysninger om sosiale og yrkesmessige forhold
- Opplysninger om kronisk sykdom og behandling av denne
- Aktuell medikasjon

Appendix 4

Dato		Dato		Dato	
Aktivitet		Aktivitet		Aktivitet	
Varighet		Varighet		Varighet	
Intensitet		Intensitet		Intensitet	
Kommentar		Kommentar		Kommentar	
Dato		Dato		Dato	
Aktivitet		Aktivitet		Aktivitet	
Varighet		Varighet		Varighet	
Intensitet		Intensitet		Intensitet	
Kommentar		Kommentar		Kommentar	
Dato		Dato		Dato	
Aktivitet		Aktivitet		Aktivitet	
Varighet		Varighet		Varighet	
Intensitet		Intensitet		Intensitet	
Kommentar		Kommentar		Kommentar	
Dato		Dato		Dato	
Aktivitet		Aktivitet		Aktivitet	
Varighet		Varighet		Varighet	
Intensitet		Intensitet		Intensitet	
Kommentar		Kommentar		Kommentar	

Registration of habitual activity.

Appendix 5

Dato		Dato		Dato	
Treningssted		Treningssted		Treningssted	
Oppvarming hva og lengde		Oppvarming hva og lengde		Oppvarming hva og lengde	
Rep/antall kg serie 1		Rep/antall kg serie 1		Rep/antall kg serie 1	
Rep/antall kg serie 2		Rep/antall kg serie 2		Rep/antall kg serie 2	
Rep/antall kg serie 3		Rep/antall kg serie 3		Rep/antall kg serie 3	
Rep/antall kg serie 4		Rep/antall kg serie 4		Rep/antall kg serie 4	
Kommentar til økt og dagsform		Kommentar til økt og dagsform		Kommentar til økt og dagsform	
Dato		Dato		Dato	
Treningssted		Treningssted		Treningssted	
Oppvarming hva og lengde		Oppvarming hva og lengde		Oppvarming hva og lengde	
Rep/antall kg serie 1		Rep/antall kg serie 1		Rep/antall kg serie 1	
Rep/antall kg serie 2		Rep/antall kg serie 2		Rep/antall kg serie 2	
Rep/antall kg serie 3		Rep/antall kg serie 3		Rep/antall kg serie 3	
Rep/antall kg serie 4		Rep/antall kg serie 4		Rep/antall kg serie 4	
Kommentar til økt og dagsform		Kommentar til økt og dagsform		Kommentar til økt og dagsform	
Dato		Dato		Dato	
Treningssted		Treningssted		Treningssted	
Oppvarming hva og lengde		Oppvarming hva og lengde		Oppvarming hva og lengde	
Rep/antall kg serie 1		Rep/antall kg serie 1		Rep/antall kg serie 1	
Rep/antall kg serie 2		Rep/antall kg serie 2		Rep/antall kg serie 2	
Rep/antall kg serie 3		Rep/antall kg serie 3		Rep/antall kg serie 3	
Rep/antall kg serie 4		Rep/antall kg serie 4		Rep/antall kg serie 4	
Kommentar til økt og dagsform		Kommentar til økt og dagsform		Kommentar til økt og dagsform	

Rep, repetitions. Kg, kilogram.

Training routine. Registration of load and repetitions.

Table 4. Strength training studies in elderly

Strength trials in older individuals:							
study:	groups, age, sex:	health and training history:	intervention time:	training design:	conducted exercises:	muscular strength adaptations:	
Reeves et al., 2004.	(74.3±3.5 y/o): N=4 men, N=5 female; (67.1±2 y/o): C=4 men, C=15 female (67.1±2 y/o)	healthy, active	14 weeks	2 sets, 10 reps, periodised, 3x/week	leg press, leg extension	5RM increased 23%	
Brentano et al., 2008.	Ncircuit training=10 Nstrength training=9 C=9; female	postmenopausal women, occasionally active in recreational activities, all had bone loss, all supplemented hormonal therapy	24 weeks	CT: 2-3 sets, 20-10 reps, 45-60% 1RM; ST: 2-4 sets, 20-6 reps, 45-80% 1RM, 3x/week	full body training	lower limb dynamic strength increased 39,4% in CT and 42,2% in ST	
Persh et al., 2009.	N=14 (61.1±4.3 y/o) C=13 (61.6±6.6 y/o); female	healthy, active	12 weeks	2 sets, 10-12 reps, weekly increased load, 3x/week	lower limb ST	1RM increased 59% in leg press	
Botero et al., 2013.	N=23 (63.02±4.42 y/o); female	healthy, physically inactive and not taking hormonal therapy for at least 6 months prior study	12 months	3 sets, 6-14 reps of 1RM, load periodised, 2x/week	full body ST, including 45° leg press	1RM increased 100%, 45° leg press	
Salvesen, S., 2013.	N=33 (60-80 y/o); men	healthy, not systematic trained in strength before (<6 months)	12 weeks	1-4 sets, 3-15 reps, periodised, 3x/week	full body, multi- and single-joint	1RM increased 30%	
Kanegusuku et al., 2015.	(60-80 y/o): N=5 men, N=7 female, C=2 men, C=11 female	healthy, with no strength training experience	16 weeks	2-3 sets, 8-10 reps, periodised, 2x/week	leg press	1RM increased 46%	
Unhjem et al., 2015.	N=9 (65-85 y/o), C=8 (20-30 y/o); men	healthy, active	8 weeks	4 sets, 12 reps, 75-80% 1RM, 3x/week	leg press	1RM increased 26%	
Haraldstad et al., 2017.	N=49 (60-81 y/o); men	healthy	12 weeks	load and volume periodised, 3x/week	leg press, leg extension, biceps curl	1RM increased 16%	
Wang et al., 2017.	N=11 (72±3 y/o); men	healthy, active	8 weeks	4 sets, 4 reps. 85-90% 1RM, 3x/week	squat on squat machine	1RM increased 68%	

N, number of individuals in test group; C, number of individuals in control group. y/o, years old. ST, strength training. Reps, repetitions. RM, repetition maximum. Data presented as mean ± SD. Significantly different from pre-test (p<0.05).

Table 5. Strength training studies in young

Strength trials in younger individuals:						
study:	groups, age, sex:	health and training history:	intervention time:	training design:	conducted exercises:	muscular strength adaptations:
Campos et al., 2002.	Nlow rep group= 9 (21,1±1,5 y/o); C=5 (31,6±9,8 y/o); men	healthy, untrained	8 weeks	4 sets, 3-5 reps, 3x/week	leg press, leg extension, squat	1RM increased 61% in leg press
Ahtiainen et al., 2003.	N= 8 (34,4±4,4 y/o); Nstrength athletes=8 (30±6,5 y/o); men	healthy, active	21 weeks	5 sets, 10 reps 2x/week	heavy resistance training, leg press	1RM increased 19% in N, and 7% in Nstrength athletes
Fimland et al., 2009b.	N= 10 (23±3 y/o); C=9 (24±2 y/o); men	healthy, experienced in ST, but not trained systematically in legs	8 weeks	4 sets, 4 reps, 85-90 1RM, 3x/week	leg press	1RM increased 44%

N, number of individuals in test group; C, number of individuals in control group. y/o, years old. ST, strength training. Reps, repetitions. RM, repetition maximum. Data presented as mean ± SD. Significantly different from pre-test (p<0.05)

Table 6. Comparison of muscular adaptations to ST between young individuals and older adults (ST adaptations taken from table 4 and 5)

		age (years):	ST adaptations:
previous studies	young individuals	20-35	1RM increased 42%
	older individuals	60+	1RM increased 45%
present study: Bein Press	young individuals	20-29	1RM increased 19,5%
	older individuals	60+	1RM increased 22,9%
	whole study population	20-60+	1RM increased 23,8%

Data presented as mean ± SD. Significantly different from pre-test (p<0.05).