UNIVERSITY OF AGDER

Work economy following strength training in elderly

Alterations in muscle strength, muscle thickness and lean mass upon work economy in elderly men following 12 weeks of strength training

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Abstract

AIM: To investigate if alterations in muscle strength, muscle mass and muscle thickness were followed by changes in work economy.

METHODS: Fifty elderly men (60 – 81 years) followed a 12 week undulating periodized strength training program: Lean mass (Muscle mass; Dual-energy X-ray absorptiometry), muscle strength (1RM; one repetition maximum, in leg press and leg extension), and muscle thickness (ultrasound; vastus lateralis and rectus femoris) were measured before and after the intervention. Work economy, determined as body mass adjusted oxygen consumption, were assessed while walking on a treadmill at 5 km/h at three different inclinations: 0 %, 4 % and 8 %; 5 min at each work load.

RESULTS: In addition to significant increases in muscle strength and muscle mass ($p < 0.001$), the participants significantly improved their work economy at the three different work-loads by, respectively, 4.0% (0.3, 7.4) (median and 95% confidence intervals ($p = 0.01$)), 2.8% (-1.4, 7.1 ($p = 0.016$)) and 2.5% (-0.2, 5.0 ($p < 0.006$)). No significant positive associations were found between changes in muscle strength, muscle mass or muscle thickness upon work economy.

CONCLUSION: 12 weeks of strength training improved work economy during inclined walking in elderly men. However, the results suggest that other factors than changes in muscle strength, mass and thickness are the mechanisms behind the improved work economy.

Keywords: resistance training; submaximal endurance; healthy old

Due to the word-limitation of the master thesis, are results, discussion and conclusion of the present study are included in the attached article only. Attachments to the master thesis are included at the end.

Sammendrag

FORMÅL: Undersøke om endringer i muskelstyrke, muskelmasse eller muskeltykkelse ble fulgt av forandringer i arbeidsøkonomi.
METODE: Femti eldre menn (60 – 81 år) gjennomførte et periodisert styrketreningsprogram: Lean masse (Muskelmasse; dobbel røntgenabsorpsjonsmetri), muskelstyrke (1RM; en repetisjon maksimum, i beinpress og kneekstensjon) og muskeltykkelse (ultralyd; vastus lateralis og rectus femoris) ble målt før og etter intervensjonen. Arbeidsøkonomi, definert som oksygenopptak justert for kroppsmasse, ble målt gående på tredemølle ved 5 km/t på tre ulike hellninger: 0 %, 4 % and 8 %; 5 min på hver belastning.
RESULTATER: I tillegg til signifikante økninger i muskelstyrke og muskelmasse ($p < 0.001$), forbedret deltakerne arbeidsøkonomien på de tre ulike arbeidsbelastningene med henholdsvis 4.0% (0.3, 7.4) (median og 95% konfidensintervaller ($p = 0.01$)), 2.8% (-1.4, 7.1 ($p = 0.016$)) og 2.5% (-0.2, 5.0 ($p < 0.006$)). Ingen positive assosiasjoner ble funnet mellom endringer i muskelstyrke, muskelmasse eller muskelykkelse på arbeidsøkonomi.
KONKLUSJON: 12 uker med styrketreningen fobedret arbeidsøkonomien hos eldre menn. Imidlertid tyder resultatene på at det er andre faktorer enn endringer i muskelstyrke, muskelmasse og muskeltykkelse som er mekanismene bak den forbedrede arbeidsøkonomien.

Nøkkelord: Styrke; submaksimal utholdenhet; aldring;

På grunn av ordbegrensninger i masteroppgaven, vil resultater, diskusjon og konklusjon kun bli presentert i vedlagte artikkel. Vedlegg til masteroppgaven følger til slutt.

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Svein Salvesen

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1 Introduction

In elderly, both muscular strength and endurance contributes to functional performance, which in turn is an important factor for maintaining a healthy, active and independent lifestyle (for review see (1)). However, the functional performance of aging muscles typically declines (2) and leads to difficulties conducting common everyday tasks. In order to reduce the physical decay, and maintain quality of life, strength training has effectively been used as a countermeasure in elderly populations (3-5). Indeed, a bout of strength training accelerate net protein synthesis in the hours and days after exercise (6), and as long as the frequency of exercise bouts is adequate, muscle mass is gained (7, 8). Importantly, the size of the muscle mass is dominating determinant for the force-generating capacity; i.e., maximal strength (9).

In addition to increases in strength and muscle mass, strength training seems to improve the capacity of the oxygen transport and/or utilization, and thus, improve the aerobic capacity in elderly subjects (10, 11). The association between strength training and endurance capacity is not a new concept. Hickson et al. (12) was among the first to demonstrate that endurance capacity can be increased by strength training. Since then, several investigators have showed that strength training improves endurance capacity in athletes (13-21), untrained adults (22, 23) and in elderly individuals (24-29). Most of these studies have measured maximum oxygen consumption ($\dot{V}O_{2max}$), and/or endurance performance test, e.g., time until exhaustion. Even though $\dot{V}O_{2max}$ is a frequently used measure of aerobic capacity, work economy (i.e., the oxygen cost of submaximal endurance) may be a better and more relevant measure to assess endurance performance among subjects with similar $\dot{V}O_{2max}$ (30). Maybe in elderly particularly, where submaximal endurance could reflect daily living activities in a more consistent way. An improved work economy would increase endurance performance by allowing a runner to run at a higher pace over a given distance, or longer at a constant speed (31). Moreover, an improved work economy in elderly could lead to lower the oxygen cost during functional tasks, leading to a higher degree of independency in this population. Interestingly, studies that have investigated traditional strength training upon work economy in healthy elderly, have failed to observe decreased $\dot{V}O_2$ while walking (28, 32, 33). Several factors following strength training are associated with improvements in work economy, and few studies have investigated this in elderly. Therefore, it is still of interest to further investigate the effect of adaptations from strength training upon work economy in elderly men.

1.1 Aims of the present study

We wanted to investigate if an alteration in muscle strength or muscle mass was followed by changes in work economy when walking horizontally and uphill, following 12 weeks periodized strength training in elderly men.

Hypotheses:

- *We hypothesized that traditional strength training would improve work economy.*
- *We hypothesized that alterations in muscle strength and muscle mass was followed by changes in work economy.*

2 Theoretical background

In the present study running economy is referred to as work economy, and been defined as the oxygen uptake required at a given absolute exercise intensity (34). An improved work economy may enhance endurance performance, because it will result in the use of a lower percentage of $\dot{V}O_{2max}$ for any exercise intensity (34), which in turn may lead to using less energy at a given pace, compared to someone with a poor work economy. A review by Larsen (35), illustrated the importance of work economy, by investigating why Kenyan athletes performed better than to non-African athletes. Small differences at $\dot{V}O_{2max}$ and O_2 utilization rate was observed, but differences were observed in work economy. This assumes that work economy is of great importance and essential in performance. Also with aging, an improved work economy could be beneficial to accomplish daily physical tasks. Several factors may however influence and affect work economy (figure 1).

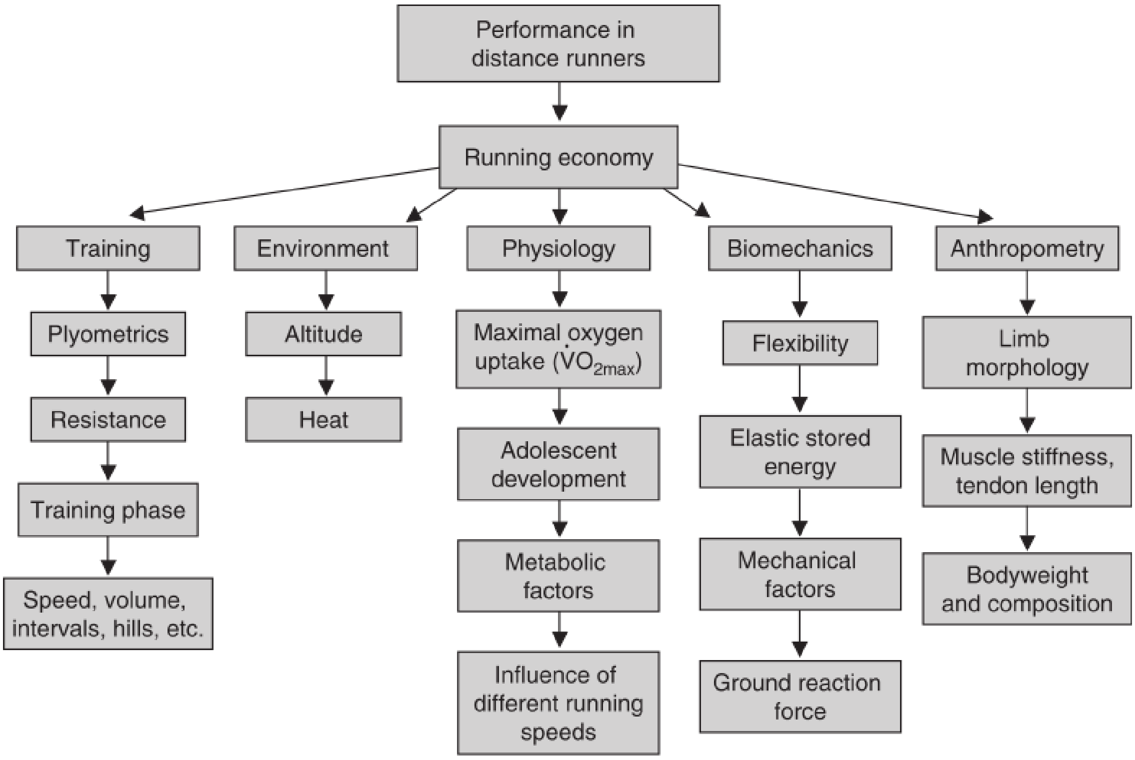

Figure 1. Factors affecting work economy (30).

2.1 Effects of strength training in elderly

With aging, a decrease in functional performance is observed from the 30th year, progressively decreasing with approximately 15% in the 6th decade of life and up to 30% in the 8th decade (36). The decrease in muscle mass (sarcopenia) involves both a loss of muscle fibers (atrophy) and number (hypoplasia), with type II fibers more vulnerable to atrophy than type I fibers (37). Especially in leg musculature, a reduction is primarily due to a loss of type II fibers, with the type I fibers in a higher degree maintained (38). A decrease in muscle mass and selective atrophy/loss of type II fibers result in reduced generate force capacity and a profound reduction in rapid force development (39). Maintenance of muscle mass with aging may further be beneficial for preventing clinical conditions (obesity, insulin resistance, diabetes, osteoporosis), and promote long-term health throughout the lifespan (40).

First in the last three decades, strength and muscle mass on elderly have become a central research area. Earlier training on elderly was largely based on low intensity endurance and flexibility training. At the end of the 1980s, Frontera et al. (41) reported that heavy-resistance training led to an increase in strength of the quadriceps muscles of older men aged between 60 and 72 years, which also were accompanied by an increase in muscle fiber size. Since then, a fast growing number of studies have verified the effectiveness and benefits of strength training in older people (11, 42-44).

In addition to increases in muscle strength and muscle mass, the aerobic capacity may be affected following strength training. Ades & Ballor (45) observed no changes in submaximal oxygen consumption in elderly men. However, the participants increased their submaximal walking until exhaustion by 9 min (38%). The increased walking performance was by the authors explained by increased leg strength (leg extension; 29%), which would allow the participants to work at a lower percentage of their peak strength, and thus reduce the contributions from anaerobic mechanisms. Improved endurance capacity following strength training has further been observed in several studies (24-26, 28). Lovell et al. (24) observed significantly increased leg strength (squat; 58%), but not an improved $\dot{V}O_2$ ($L \cdot min^{-1}$) during sub-maximum aerobic exercise in men aged 70 – 80 years. However, reduced heart rate, stroke volume, systolic blood pressure and rate pressure product was improved, leading to improved cardiovascular function. In a study by Hagerman et al. (26), elderly men (60-75 years) significantly improved leg strength (leg press; 72.3%, leg extension; 50.4%), in addition to a significantly increased peak aerobic capacity. Izquierdo et al. (25) found an increase of 41% in muscle strength (half-squat) in elderly men (64 years old), in addition an improved cycling performance (maximal workload; 6%, and submaximal workload at 2 $mmol \cdot L^{-1}$; 9% (not significant) and at 4 $mmol \cdot L^{-1}$; 8%). Also in a daily living task, Hartman et al. (28) found a significant lower $\dot{V}O_2$ (6%) in walking while carrying a box, in elderly (67 years) individuals following 26 weeks strength training. However, no significant change was found when only walking was performed.

In order to understand the potential benefits from strength training on endurance performance, the identification of variables involved seems necessary. If there are improvements in endurance capacity either $\dot{V}O_{2max,}$ lactate threshold or work economy is likely to be affected (46). Lactate threshold represents the highest workload given until the rate of lactate appearance exceeds lactate disappearance (47). This means that when the lactate production is higher than the lactate elimination it will result in an increased concentration of lactate. Studies examining effects of strength training on untrained individuals have observed an improved lactate threshold (23, 25), or no change in lactate threshold (48). $\dot{V}O_{2max}$ is mainly dependent on central cardiovascular factors (i.e. heart, lungs, and blood), to transport O_2 from the atmosphere to the working muscles. On the other hand, sub-maximal workload may in a higher degree involve peripheral mechanisms, and are primarily adaptations in the muscle (49). Since traditional strength training is unlikely to elicit an aerobic stimulus of higher than 50 % of $\dot{V}O_{2max}$, and thus an unchanged $\dot{V}O_{2max}$ (49), peripheral adaptations seems to be essential in the observed improvements in aerobic capacity after strength training (50). Although discussed, aiming for an increase in $\dot{V}O_{2max}$, an exercise intensity of 90-100% may be the most effective intensity to affect $\dot{V}O_{2max}$; however, also moderate intensities have seemed to be beneficial (51). In a review by Ozaki et al. (11), improvements in $\dot{V}O_{2max}$ following strength training were found in studies with elderly with low baseline values, i.e. $VO_{2max} < 25$ mL·kg^{-1}·min^{-1} (11). This indicates a potential to increase $\dot{V}O_{2max}$ with strength training. However, being able to increase $\dot{V}O_{2max}$ following could be inhibited by the individual potential of development (Baseline levels in $\dot{V}O_{2max}$).

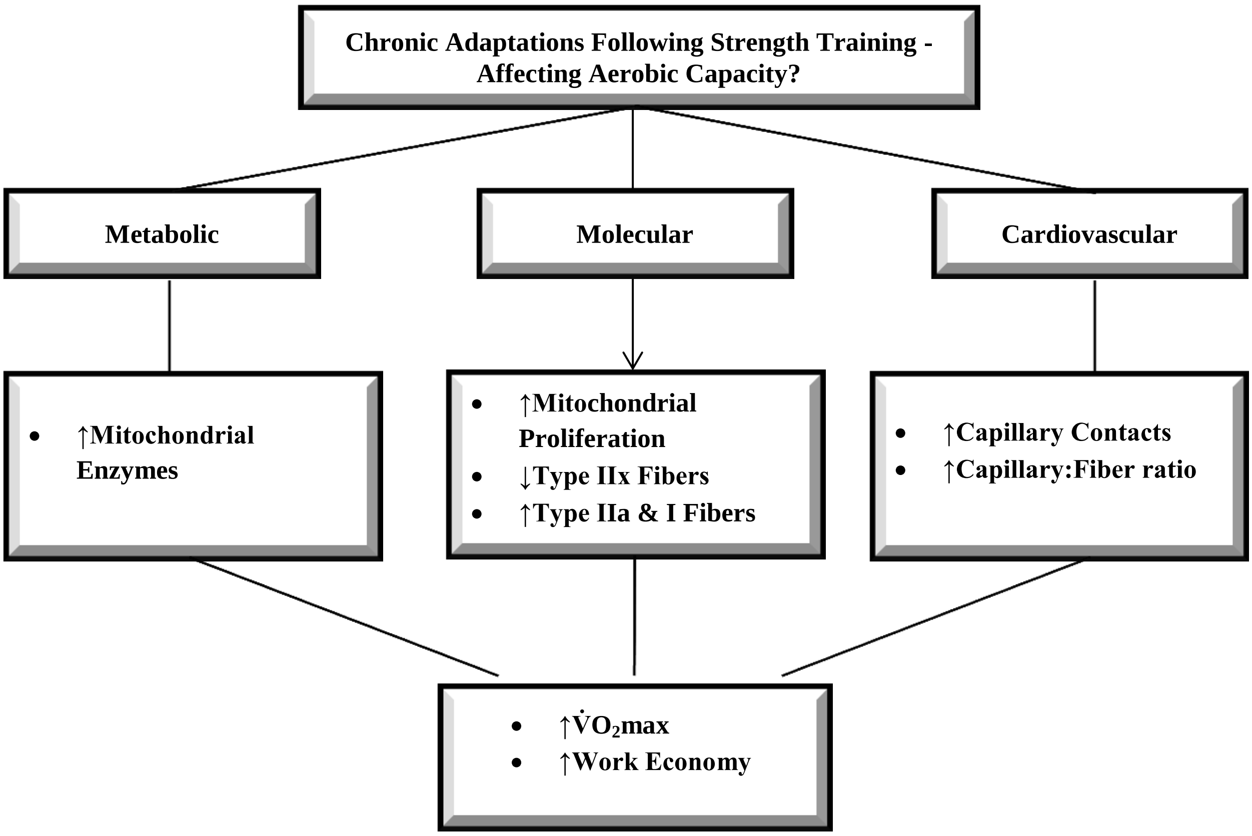

Figure 2. Schematic overview of chronic physiological adaptations and improvements in aerobic capacity following strength training. Modified after Steele et al. (46).

2.2 Adaptations from strength on aerobic capacity

The reasons for improvements in aerobic capacity seem still to be unclear, because several chronic adaptations are observed following strength training. Metabolic, molecular and cardiovascular adaptations may contribute to both enhanced $\dot{V}O_{2max}$ and work economy, and thus endurance performance (figure 2). In the following sessions, a brief collection of possible factors which may contribute to an improved work economy and endurance performance after strength training are presented.

2.2.1 Tendon stiffness

Improved work economy may be enhanced by increased tendon stiffness (52). Stiffness in muscles and tendons seems to increase elastic storage and return of energy and reduce the sub-maximal $\dot{V}_{O2}$ demand (52). Saunders et al. (30) concluded, after reviewing several studies, that it seemed to be an optimal level of stiffness which can benefit running economy.

Thereby it is not recommended to abandon stretching, because a certain degree of stiffness is required for optimal stride length, and to maximize elastic energy storage of energy. This elastic energy requires no metabolic cost and could therefore lead to improvements in running economy (30).

2.2.2 Improved neural function

Neural adaptations are essentially changes in coordination and learning that facilitate improved recruitment and activation of the involved muscles during a specific strength task (53). Specific mechanisms of neurological adaptation from strength training were investigated by Folland & Williams (53). They identified several factors which could enhance maximal voluntary contraction and rate of force development. Firing frequency, synchronization, cortical adaptations, spinal reflexes and antagonist coactivation could all contribute to rapid rise in strength at a start of a strength training program. With an increased maximal voluntary contraction, also determined as maximal muscle strength, a change in muscle fiber recruitment patterns, and a reduced relative load (relative to max) could lower the demands of the working muscles, as reviewed by Aagaard & Andersen (15). In addition, an increased rate of force development could allow for a longer relaxation time between each stride, allowing unrestricted blood flow perfusion (16). Thus, increased endurance performance may be due to improved delivery of O_2 to the working muscles.

2.2.3 Skeletal muscle fibers

The three major fiber types (i.e. type I, type IIa and type IIx) functional characteristics are largely based on the speed of enzyme activity; adenosine triphosphatase (ATPase) (54), which allows a variety of functional demands, when they vary in contraction velocity and fatigue resistance. Type I are slow twitch fibers and are the most fatigue resistant, type II are fast twitch fibers with moderate fatigue resistant, and type IIx are also fast twitch fibers, but are more sensitive to fatigue (55). With strength training, it seems to be a consensus that the muscle fiber composition may be changed, with an increase in MHC (Myosin heavy chain) type IIa at the cost of MHC type IIx (figure 3). MHC type I fibers seems only to be marginally affected by resistance training with either no change, or only very subtle changes (6, 54). However, improvements in type I fibers function, making them stronger, may also contribute to make them more fatigue resistant (56).

Figure 3. Fiber transformation observed with strength training. Modified after Phillips (7).

Results showing a shift in skeletal muscle fibers are the same in elderly, where in addition to increased muscle size, studies are showing the plasticity of skeletal muscle fibers even at older ages (57, 58).

2.2.4 Capillaries

Angiogenesis, the growth of new capillaries, is a well-documented incidence from exercising skeletal muscle (59). This capillary growth may improve the oxygen delivery capacity, which is related to endurance performance (60). In untrained subjects, strength training seems to provide stimulus for capillary neoformation. An increase in capillaries per fiber is observed following strength training (61), but the capillary density appears to remain unchanged (26), despite the presence of cellular muscle hypertrophy (62). This suggests that the increase in capillary number is proportional with the muscle fiber growth. The capillary density seems at least to be maintained following strength training, suggesting that the O_2 diffusion distance, and hence O_2 delivery, would be the same as before strength training and hence, at a pre-training level (63). However, determination of muscle capillarity and the measurements used to express capillary neoformation may be confounding, due to a wide range of measurements to identify skeletal muscle capillarization (64). Even though the capillary density remains unchanged, an increased capillary contact per fiber may be found in elderly following strength training (57). Hepple et al. (65) found increased capillary contacts and capillary to fiber ratio after 9 weeks strength training. At this point, resistance training at least seems to maintain the blood flow for exercising muscles, through an increased contact surface between the muscle fiber and the capillary. An increase in muscle mass may however be the reason for studies finding no changes in capillarization (66). Other confounding factors, in addition to the measurements used, could be study populations and age groups, training status and intensity, muscle group tested and the method of measuring these parameters (67).

2.2.5 Mitochondria

Mitochondria are the main subcellular structures that determine the oxygen demand of muscle (68). The oxygen diffuses from the capillaries to the muscle fibers and ends up in the mitochondria. Measurement of the activity of the mitochondrial enzymes is a common way to investigate the effect on mitochondria biogenesis (i.e. increased mitochondria amount and enzyme activity) following a training intervention. Both the production and the resting concentration of adenosine triphosphate are likely to be improved with strength training (69), with studies showing increased markers of aerobic metabolism (10, 70, 71).

An upregulation of the mitochondrial machinery involves β-oxidation activity and the tricarboxylic acid cycle (TCA). β-oxidation improves the capacity to "burn" fatty acids molecules, and this process involves upregulation of enzymes which transports fatty acids into the mitochondria for fat oxidation (72). The TCA cycle (also known as Krebs cycle) is considered to regulate the capacity of mitochondrial metabolism, and potential for TCA cycle involves the enzymes succinate dehydrogenase and citrate synthase (73). In elderly, findings support that resistance training stimulates components of the mitochondrial respiratory chain (74). Even though the marker enzyme citrate synthase was unchanged after 14 weeks of progressive resistance training, the results suggested that specific components of the mitochondrial function could adapt from resistance training without an increase in total mitochondrial mass. Several studies have suggested that strength training may reduce mitochondrial density (75, 76); however, studies may have failed to consider the simultaneous increase in muscle mass. The increase in mitochondrial enzyme activity from strength training, appears to provide a stimuli for the mitochondrial biogenesis and (or) an increase in the oxidative enzyme content of existing mitochondria, which in turn increases the oxidative potential (70).

The mechanisms of strength training on endurance performance and work economy still seem to be unclear. Strength training seems to have an impact on peripheral adaptations, with increased or maintenance of capillaries and mitochondria biogenesis, which subsequently may improve the capacity of muscle to utilize oxygen. In addition, muscle fiber transformation, improved neural function and tendon stiffness may all occur following strength training and improve work economy and endurance performance.

3 Methods

3.1 Design

The present study is an extension of “Smartfish, Antioxidants, Recovery and Adaptation” (SARA), aiming to investigate how high dosage with antioxidants and a Smartfish drink affects adaptation to strength training and endurance exercise in young to middle aged subjects (18-45 years) and elderly men (60-81) (Paulsen, manuscript in preparation). The design of the whole SARA-elderly study is illustrated in both the flow chart (appendix 1), and timeline (appendix 2). SARA-elderly was conducted as a double-blinded randomized placebo-controlled experiment, with three groups; antioxidant group (vitamin C and vitamin E tablets), a Smartfish group (Smartfish drink), and a placebo group (sugar water/cellulose tablets). The present study was however limited to investigate the effect of 12 week strength training intervention upon work economy in elderly men. Thus, all participants in the present study were pooled in one group.

Both pre and post testing was supervised by the same test leader. Oral and written instructions were given in conjunction to preparations prior for testing The testing was conducted over three separate days; (1) Sørlandet Hospital Kristiansand for DXA (dual-energy X-ray absorptiometry), (2) 1 RM (one repetition maximum), and (3) multiple measurements in following order: Blood sample → Inbody (Bioelectrical Impedance Analysis Method) → Questionnaire → Ultrasound → Work economy. On the day with multiple measures the tests were taken in the same order both pre and post. After an overnight fast, blood samples, Inbody and a questionnaire were taken before a meal was served. Muscle thickness was measured at least 30 minutes after the meal for the first participant, and then the work economy test. A four-day diary registration was carried out to assess their energy intake (77). Daily physical activity was recorded for four consecutive days with the activity monitor SenseWear Pro$_3$ Armband (BodyMedia, US), both pre and after 10 weeks of the intervention. Subjects were instructed to maintain usual food and physical activity habits.

3.2 Ethics

The study complied with the standards set by the Declaration of Helsinki and was approved by the regional committee for medical and health research ethics; south-east before initiation (appendix 3). All subjects were given a written informed consent they signed, before entering the study (appendix 4).

3.3 Subjects

Elderly males (60 – 81 years) were recruited through advertising, from the local community in Kristiansand. Both newspaper and flyers was used (appendix 5). The subjects had not conducted systematic strength training during the last 6 months before entering the study. To ensure that the subjects were healthy and able to participate in heavy strength training, a medical screening at the hospital of southern Norway was conducted before entering the study. Exclusion criteria were any overt disease (COPD, cancer, heart failure etc.), which could influence the results, and use of medication or supplements that could interfere with the tests. See table 1 for comprehensive inclusion/exclusion criteria.

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

Inclusion:	**Exclusion:**
Male	Female
60 – 80 years	Under/over 60-80
Not systematic resistance training for at least 6 months (>1 sessions a week)	Disabilities to perform strength training
	Use of supplements under the intervention
	Medication or disease which may affect the training adaptation

A total of 200 were interested and attended an information meeting at University of Agder (UiA). After completing a registration questionnaire (appendix 6) regarding exclusion criteria (table 1), 71 participants were invited to participate in the study. Sixteen of the participants did not meet the requirements set by responsible physician after the health screening at Sørlandet Hospital Kristiansand, and were excluded from the study. In addition, two participants decided to drop out of the study because of personal circumstances. During the intervention, three more participants dropped out of the study because of injuries. The reasons were one hip operation and a broken ankle, not related to the strength training, and a biceps rupture during 1 RM testing. Furthermore, one of the participants was excluded from Leg Extension 1RM test, because of a painful knee, but is included in all other analyses.

Seventeen participants were excluded from analyses in the work economy test because of high values in blood lactate (> 2.2 $\text{mmol}\cdot\text{L}^{-1}$), leaving us with 33 participants analyzed.

3.4 Procedure

All subjects started with 2 weeks familiarization period without supplementation, which focused on proper exercise techniques and “wash out” previous training regimes, as well as familiarization to the 1RM tests. The exercise volume increased progressively from 1-2 warm-up/technique (40-60% of 1RM) sets and one exercise set (10RM) to 1-2 warm-up and 2-3 exercise sets per exercise (10RM). At the end of the 2 weeks period, all subjects conducted the 1RM tests as described in chapter 3.5.4. This was done to minimize the learning effect in these tests.

During the intervention, the 12 weeks of strength training were conducted with an undulating periodized profile (78). The protocol included 3 full-body sessions per week, where all the major muscle groups were included. Two of the sessions each week were “moderate” (8-10 RM, with 1 min break between sets), and one was changed between “heavy” (3-5 RM, with 2 min break between sets) and “light” (13-15 RM, with 45 seconds break between sets)” every second week. The strength-training program (appendix 7) was designed to give large metabolic stress (i.e., oxidative stress), and the intention was to stimulate as much muscle growth as possible. The number of sets per exercise was increased progressively from 1 to 4 sets during the first 10 weeks, and then reduced with 1 set each of the last 2 weeks of the intervention. The subjects conducted one additional “warm-up” set at approximately 50% of their target weight in each exercise before the main sets started. The movement velocity was instructed to a minimum of 1 second in the concentric phase, and 2 seconds in the eccentric phase. In addition, all training sessions were timed and synchronized, according to the rest intervals between sets. All subjects received an individual exercise diary before each session, with individual weight load for every exercise (appendix 8). Resistance was weekly adjusted. The last set of each exercise in one of the “moderate” sessions a week, and in every light and heavy session, was performed as a maximum repetition test at the given weight that was written down in the prefilled diary. If the maximum repetition result fell outside the given repetition interval (appendix 7), the resistance was adjusted before the next session.

3.5 Measurements

3.5.1 Work economy

Work economy was measured while walking on a motor driven treadmill (Woodway ELG55, Weil am Rhein, Germany), without using hand rails, for a total of 20 minutes. Before the test, height and weight was measured with Inbody 720 (Direct Segmental Multi-frequency Bioelectrical Impedance Analysis Method, BioSpace Co., Ltd., Seoul, South-Korea), and they were instructed relative to the test protocol. The participants were also equipped with a face mask and heart rate monitor (Polar S610i, Polar Electro OY, Kempele, Finland) before/during the warm up to ensure that all devices functioned, and to make them comfortable walking on the treadmill. Equipment was calibrated according to instructions from manufacturer every 3rd test, and was repeated until the difference between consecutive calibrations was less than 1% After a warm up of 5 minutes (2 minutes at 3 km/h → 2 minutes at 4 km/h →1 minute at 5 km/h), the participants walked 5 minutes at three different inclinations: 0%, 4% and 8. The oxygen consumption ($\dot{V}O_2$) was measured in 30 seconds intervals with Oxycon Pro's breath to breath system (Oxycon, Jaeger BeNeLux Bv, Breda, Netherlands). In addition, blood lactate (La^-), heart rate (HR), respiratory gas exchange ratio (RER) and minute ventilation (V_E) was measured at each work load. Steady state was reached within three minutes walking at each work load, and average values were obtained the last two minutes at each work load. Capillary blood lactate was collected from fingertip after each work load with Arcray Lactate Pro LT-1710 (Arkay Inc. Kyoto, Japan), with the participants standing with spread legs on the treadmill. After a wash out with spirit and a finger stick, the first blood drop was wiped away, while the second was collected and analyzed. Any extreme values were excluded when collecting average measurements the last two minutes at each work load. The lactate testing equipment measured a minimum of 0.8 $mmol \cdot L^{-1}$, resulting in lactate levels below 0.8 unidentifiable. Measures below this limit was set to 0.8 $mmol \cdot L^{-1}$ when analyzing.

3.5.2 Dual-energy X-ray absorptiometry

Body composition measured by one experienced observer was assessed by dual-energy X-ray absorptiometry (DXA; GE-Lunar Prodigy, Madison, WI, USA). Both weight and height was measured before the test, and bodily ornaments (watches, jewelry etc.) were removed. The participants were told to lay down at the DXA machine after the test leaders instruction, with hands along the side, slightly away from the body and with the legs straight and internally rotated. Participants were scanned from head to toe in supine position, providing values for bone mineral content (BMC), non-bone lean tissue, and fat mass in total body, as well as in arms, legs and trunk separately. Test-retest analyses from 62 scans in 31 participants demonstrated intra class correlation of 0.99 (all with $p < 0.001$) for percentage of body fat, fat mass and lean mass. Limits of agreement (mean differences ± 1.96 standard deviation (SD) of the difference) were -0.3 ± 2.14% for percentage of body fat, -0.26 ± 1.64 kg for fat mass and -0.23 ± 1.75 kg for lean mass, with 97% - 100% of the values within two SD. Coefficients of variation (CV); 1.5% in lean mass, 3.3% in fat mass and 3.6% in percentage of body fat.

3.5.3 Ultrasound measurements

A single, previously trained examiner performed all of the ultrasound measurements. The muscle thickness was measured in vastus lateralis, rectus femoris and in the arm flexors (biceps brachii and brachialis) using a brightness mode (B-mode) ultrasonographic apparatus (LogicScan 128 CEXT-1Z kit, Telemed, LT), with linear probe of 40mm width and an excitation frequency of 9 MHz. Ultrasound settings such as focal depth, image depth, power and gain were optimized to best identify the collagenous tissue that defines the outer border of the muscle. All subjects were instructed to lay down on a bench with the legs relaxed in a supine position. Muscles in the dominant arm or foot were analyzed. Great care and excessive use of gel was used to ensure that minimal pressure was applied to the muscle tissue when an image was scanned. The vertical diameter of vastus lateralis and rectus femoris were measured at a distance equal to 40% of the femur length, distally. Scan locations for vastus lateralis and rectus femoris were located between the lateral epicondylus and the great trochanter major of the femur. Ultrasound images of the arm flexors were taken in two places; 50%, and 30% of the humerus length, distally. Scan locations were found between the epicondylus lateralis and the proximal part of the humerus. Locations were identified using ultrasound when possible. Probe position in each measurement were recorded on acetate paper to ensure identical placement, and sets of three consecutive US images were scanned for later analyses in each position.

The images where analyzed with the program ImageJ (version 1.46r, National Institutes of health, USA) widely used for this purpose (79, 80). All the images where analyzed blinded and at random order, by the same investigator. The vertical diameter of each muscle was measured on the inner edge of the muscle in three locations. The average of the measurements in three pictures of each position was used as the muscles thickness in rectus femoris and vastus lateralis, and further analyzed. The same was done in armflexors, but additionally the average of the two locations was used. Test-retest analyses from 20 scans in 10 subjects demonstrated intra class correlation from 0.98 to 0.99 (all with $p < 0,001$) for muscle thickness of armflexors, rectus femoris and vastus lateralis. Limits of agreements were 0.2 ± 1.0 mm for muscle thickness in the armflexors (biceps brachii and brachialis), 0.1 ± 0.6 mm for muscle thickness in rectus femoris, and 0.6 ± 1.1 mm for muscle thickness in vastus lateralis. CV; 1.55% in armflexors (biceps brachii and brachialis), 1.58% in rectus femoris and 2.45% in vastus lateralis.

3.5.4 One repetition maximum

Leg extension (LE; TechnoGym, Italy), leg press (LP; TechnoGym, Italy) and scott curl (SC; TechnoGym, Italy), was assessed to measure 1RM (one repetition of maximum). 1 RM was performed with one arm (SC) or one leg (LE and LP) separately. In analyzes and results, both left and right arm/leg together was used as total value. The warm-up consisted of four sets with gradual increasing load and descending repetitions; (10 reps at 40-50% of 1RM, 6 repetitions at 60-70% of 1RM, 3 repetitions at 80-90% of 1RM, and 1 repetition at 95% 1RM). After the warm-up, the participants had four attempts on each arm/leg for the three test exercises, where the first attempt was customized to around 5% under expected 1RM after the familiarization. After the first attempt the load was increased until maximum was found and the lift was accepted, as further explained in an approved lift for the three different exercises. Three participants at each test first tested 1RM at LE, moving further to SC and then LP at the end. The rest interval between each warm-up set was 2 minutes, and 30 to 60 seconds between each leg/arm. When attempting for 1RM, the rest period was for a minimum 2 minutes. The minimum increase of load at the LE was 2.5 kg, for the LP 5 kg, and for the SC 1 kg. All the test exercises had the same test-leader before, during and after the intervention, and the participants were verbally encouraged at each attempt for 1RM. The 1RM test was conducted pre and post, and after 4 and 8 weeks.

Leg extension

The test-leader individually adjusted both the back support and the leg pad at the first test. The settings were noted. The leg pad was set to just above the shoe, with the other leg outside the pad, and that the backside at any time was in contact with the chair. Hands were placed around handles at the apparatus. The movement started at a standard level (ROM; Range Of Motion; level 2), and piece of tape marked the height of an approved attempt.

Seated scott curl

The subjects/test leader adjusted the height of the seat to ensure that chest and axillary were close to the pillow in seated position, as well as the upper arm and elbow was linked to the pillow. The settings were noted. One arm at a time was placed between markers to ensure a lift without rotation of the arm. The arm was placed in supine position, and the attempt was approved if the arm went straight up from extended position and up to vertical position without any rotation of the arm or body. The other arm was placed below the pillow.

Leg press

The subjects/test leader adjusted the seat so the angle of the knee was 80 degrees. The backseat was always in upright position, with shoulder pads individually adjusted to ensure a stabile position (same knee angel) under the lift. The settings were noted. The foot was placed on a marked spot at the panel, with the other foot placed outside the panel. An approved lift was satisfied when the leg was at full stretch.

3.6 Statistics

All statistical analyzes were performed with SPSS Statistics 19.0 (Statistical Product and Service Solutions, Chicago, IL, 2010). Tables were created in Excel 2010 (Microsoft Office, 2010). Subject characteristics and body composition are reported as mean and SD. Body composition pre and post was measured with paired samples t-test. Due to non-normality, non-parametric tests were used when analyzing muscle strength, muscle mass, muscle thickness and work economy. Wilcoxon's two-related-samples test was used to compare variables before (Pre) and after (Post) the 12 week strength training intervention. Spearman's correlations coefficient was used for determine the relationship between the measured variables. All results are presented as median and 95% confidence intervals (CI). Variables were considered significantly when $p < 0.05$.

4 Method discussion

4.1 Design

Experimental research attempts to establish cause-and-effect relationships, where an independent variable is manipulated to judge its effect on a dependent (81). Cause-and-effect relationships can only be established by a well-designed experiment, and it is crucial that no other reasonable explanation exists for the changes in the dependent variable except the manipulation of the independent variable. Thus, experimental design seemed to be the most appropriate method to investigate the aim of the present study. All participants were pooled in one group, and thus, no control group was included. The lack of a control group could make it difficult to generalize. Further, concluding that changes in work economy were a result of the strength training, could be considered problematic, due to no comparable control group. Physical activity registration was carried out before and during the intervention, and the participants were instructed to maintain their regular activity as prior to the intervention.

4.2 Study sample

In the present study we included 71 participants, however, due to the medical screening, injuries and blood lactate level during the work economy test (> 2.2 mmol·L^{-1}), we completed with a total of 33 participants included in the analyses. With a SD of 6, we had 95% power to detect a true mean group difference of 4%, with a minimum of 33 participants (alpha: 0.05; (G*Power, Version 3.010) Thus, we considered to have enough power to detect significant changes in work economy. Further, the participants were highly motivated throughout the intervention, where attendance was 33.4 sessions out of a total of 35 sessions (95.4%).

The primary weakness in the present study was the lack of a control group, which makes the results difficult to generalize. Being able to generalize the results, it is essential to determine whether an elderly population would differ significantly from the participating sample in the present study. First of all, the sample in the present study were healthy elderly, reported being physically active participating in either walking, running or cycling activities prior the intervention. When participating in the present strength training intervention, and not being that physical active in endurance types of activities as before entering the study, could possible interfere with the work economy test results. Second, the inclusion/exclusion criteria ruled out elderly with physical injuries or use of medication which could interfere with the results. Further, considered the blood lactate level limit (2.2 mmol·L^{-1}), participants with blood lactate < 2.2 mmol·L^{-1} was on average near one hour more physical active compared with those > 2.2 mmol·L^{-1} although not significant ($p = 0.158$). No difference in muscle strength was observed between the excluded and included participants. Third, the assumptions of elderly interested in participating in such a training intervention are more healthy and active compared to others in the same age group.

4.3 Measurements and procedure

In general, testing in sports science is necessary to identify effects of a training intervention. To increase the validity and reliability of the measurements, the testing was conducted at approximately the same time of day both at baseline and after the intervention. Further, the participants were instructed not to conduct physical activity before testing. Moreover, to maintain a high degree of reproducibility, standardized protocols were followed, and the same test leader supervised the same tests both pre and post the intervention.

4.3.1 Dual-energy X-ray absorptiometry

Several methods are being used to measure body composition, each with pros and cons. Even though Dual-energy X-ray absorptiometry (DXA) originally was designed to measure bone mineral density to diagnose osteoporosis (82), body composition measurements with DXA offers a fast and easy assessment of body fat and bone free lean mass, and is considered superior to many other methods (for review see (83)). When evaluating body composition measurements by DXA, this is done upon the 4-compartment model (water, bone mineral mass, fat, and residual), which currently is regarded as the “gold standard” (82). This method requires specialized laboratory equipment, not available in the present study. However, DXA is a 3-compartment model (fat, soft lean tissue, and bone mineral), and several studies have proven measurements of body composition with DXA being valid and reliable in measurement of body fat mass and bone free lean mass (84, 85). This was further supported by test-retest analyses in the present study, which revealed reliable measurements in fat mass, percentage of body fat and lean mass.

4.3.2 Ultrasound imaging

Ultrasound imaging may serve as a simple, portable, inexpensive and accurate measurement of human muscles in vivo, even though magnetic resonance imaging (MRI) is considered “the gold standard" (86). Several investigators have suggested ultrasound to be a worthy alternative to MRI, being both valid and reliable (86, 87). However, some considerations should be mentioned with ultrasound imaging. Too much pressure on the skin with the transducer could lead to a compressed muscle, leading to low accuracy when processing images (87). Further, when measurements are done over time, relocation of the transducer should be placed on the exact same spot to ensure reliable measurements (86). In the present study a trained researcher conducted the measurements, excessive use of gel was used, and acetate paper relocated identical placement. Test-retest analyses revealed reliable measurements in ultrasound imaging in the present study for both vastus lateralis and rectus femoris. Moreover, lack of uniformity with muscle growth and acute swelling of the muscles with physical activity prior measurements (87), could lead to errors. To minimize confounding errors, participants were instructed not to conduct hard physical activity prior testing, and further, the participants were tested approximately same time of day both pre and post.

4.3.3 One repetition maximum

Even though a standardized protocol in 1 RM testing, confounding variables may affect the results from 1RM testing. The participants were instructed to rest, and eat normally, without any hard exercise the day before testing, to ensure recovery of the capacity of force production in the elderly participants would be similar (88). The participants were not informed about their pre test results, due to psychological interference. The minimum increase of load (Scott curl: 1kg, leg press: 5 kg and leg extension: 2.5 kg) when attempting for 1RM, may have caused in some way incorrect measurements. The participants will during the 1RM test encounter a weak point. This point, also called the "sticking point", is where the neural stimulation needs to be at the highest to succeed the movement. Even with a minimum of 2 minutes rest between each 1RM attempt, one may notice some degree of fatigue in the working muscle, and thus confounding results. The use of maximal voluntary contraction (MVC) was an alternative we thought about using for testing maximal strength. This method may have higher test-retest reliability, due to a high level of assessments control (89). However, reliability in 1RM testing in untrained and middle-aged individuals when a familiarization session is included seems sufficient to measure maximal strength in an elderly population (90). Thus, due to equipment and practical implications 1 RM was conducted in the present study.

In addition to the described 1 RM exercises, testing calf strength before and after the intervention would have been interesting due to the incline work economy protocol in the present study. With inclination, strengthening of plantarflexion could improve the power during the push-of phase when walking, and in turn, increase walking speed and reduce the metabolic cost of walking (91). Moreover, testing functional tasks as stair climbing, chair rising and walking with a load, could further detect an improved functional capacity.

4.3.4 Work economy test

The work economy test was established according to procedures at the University of Agder. Even though the Douglas bag still serves as the “gold standard”, computerized models such as the breath-by-breath analysis is in recent years a more used method. Oxygen Pro’s breath-by-breath demonstrated to be an accurate and a faster system for metabolic variables (92). The validity and reliability for Oxygen Pro’s breath-by breath, is further supported by Carter & Jeukendrup (93) comparing Oxygen Pro and Douglas bags.

With walking on a treadmill compared to walking on the ground, confounding variables are effectively eliminated, such as air and wind resistance. Testing and collecting data in a laboratory on a motor driven treadmill may have implications in elderly due to balance and coordination, and maybe a lack of experience of walking on a treadmill. In the present study the participants did not get any more familiarization with walking on a treadmill than the “warm-up” before each test. This warm-up was prolonged if the participant felt uncomfortable walking on the treadmill or wearing the mask. A “learning effect” may occur during submaximal treadmill walking (94), and thus, lower the metabolic cost and improve work economy. In addition, several factors like footwear, time of testing, prior training activity and nutritional status, may affect intra-individual variation in work economy (95). However, each participant had the same preparations both pre and post testing. An overnight fast was conducted before a meal was served, and the participants rested for a minimum 30 min (ultrasound imaging) before the work economy test. Recommendations from a review by Saunders et al. (30) suggest that workloads below lactate threshold should be used, due to more stable measures of work economy, therefore, walking seemed appropriate. In addition, we preferred walking because it reflects daily living activities in elderly in a more consistent way. Walking was also preferred in order to achieve aerobic steady state measurements.

Participants with blood lactate level higher than 2.2 mmol·L^{-1}, were excluded in the analyses, as we wanted the aerobic energy system to be the main contributor to the energy expenditure. Lactate values between 2.0 mmol·L^{-1} and 2.5 mmol·L^{-1} was thought of being appropriate to keep the participants in aerobic steady state. However, 2.2 mmol·L^{-1} was the lowest value measured below 2.5 mmol·L^{-1}, and was thus used as a cut-off point and exclusion criteria.

4.4 The strength training protocoll

The periodized strength training intervention in the present study were performed with the goal to maximize muscle mass. Even though it may be beneficial for functionality and mortality in elderly (96), an increase in muscle mass, which in turn could lead to an increase in body mass, is not considered beneficial for endurance athletes wanting to maximize their endurance performance. Increased body mass could increase the muscle force needed to work against gravity, and in addition increase the diffusion distance in working muscle cells which could lead to impaired transport of glucose and free fatty acid (15). A review by Yamamoto et al. (97) highlights the effects of concurrent strength and endurance training upon endurance performance and work economy among highly trained runners. The findings were that their regular endurance training supplemented with plyometric or heavy resistance exercises both improved endurance performance and running economy. Combining endurance and strength training may increase muscle strength even in the absence of muscular hypertrophy, due to the interference effect (98). Different strength exercises are used for different athletes, due to the different demands in sport. While runners and cyclists mainly use leg exercises, a cross country skier obviously also want to strengthen upper body for muscles involved in the movement. The training exercises performed in the present study included all major muscle groups in both upper and lower body, and may thus not be optimal for improving only work economy and endurance performance while walking, but further an overall fitness. Further, the use of free weights and multi-jointed exercises could possible improve balance and coordination. In untrained and elderly, when performing strength training alone, an approach to a more cyclic strength training regimen compared to traditional strength training, seems to be the most efficient to improve work economy and endurance performance (32, 99), however, not an universal finding (27). A key factor in improving work economy and endurance performance seems to be intense muscular contraction (46). In the present study the last set of each exercise in one of the "moderate" sessions each week, and in every light and heavy session, was performed until failure. This could in line with the suggestions from the review by Steele et al. (46), lead to increased work economy and endurance performance in the elderly included in the present study. In addition, in both the “light” and the “moderate” session, the rest intervals between sets did not exceed 1 minute, possibly leading to improved aerobic capacity.

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Alterations in muscle strength, muscle thickness and lean mass upon work economy in elderly men following strength training

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Abstract

The aim was to investigate if alterations in muscle strength, lean mass and muscle thickness were followed by changes in work economy. Fifty elderly men (60 – 81 years) followed a 12 week periodized strength training program. Lean mass, muscle- strength and thickness were measured before and after the intervention. Work economy was assessed while walking on a treadmill at 5 km/h at three different inclinations: 0 %, 4 % and 8 %. Work economy improved at the three different work-loads by, respectively, 4.0% (0.3, 7.4) (median and 95% confidence intervals ($p = 0.01$)), 2.8% (-1.4, 7.1 ($p = 0.016$)) and 2.5% (-0.2, 5.0 ($p < 0.006$)). No significant positive associations were found between changes in lean mass muscle-strength or thickness upon work economy. 12 weeks of strength training improved work economy during inclined walking in elderly men. However, the results suggest that other factors than changes in lean mass, muscle- strength and thickness are the mechanisms behind the improved work economy.

Keywords: resistance training; submaximal endurance; healthy old

Introduction

In elderly, both muscular strength and endurance contributes to functional performance, which in turn is an important factor for maintaining a healthy, active and independent lifestyle (for review see (1)). However, the functional performance of aging muscles typically declines (2) and leads to difficulties conducting common everyday tasks. In order to reduce the physical decay, and maintain quality of life, strength training has effectively been used as a countermeasure in elderly populations (3-5). Indeed, a bout of strength training accelerate net protein synthesis in the hours and days after exercise (6), and as long as the frequency of exercise bouts is adequate, muscle mass is gained (7, 8). Importantly, the size of the muscle mass is dominating determinant for the force-generating capacity; i.e., maximal strength (9).

In addition to increases in strength and muscle mass, strength training seems to improve the capacity of the oxygen transport and/or utilization, and thus, improve the aerobic capacity in elderly subjects (10, 11). The association between strength training and endurance capacity is not a new concept. Hickson et al. (12) was among the first to demonstrate that endurance capacity can be increased by strength training. Since then, several investigators have showed that strength training improves endurance capacity in athletes (for review see (13)), untrained adults (14, 15) and in elderly individuals (16-21). Most of these studies have measured maximum oxygen consumption ($\dot{V}O_{2max}$), and/or endurance performance test, e.g., time until exhaustion. Even though $\dot{V}O_{2max}$ is a frequently used measure of aerobic capacity, work economy (i.e., the oxygen cost of submaximal endurance) may be a better and more relevant measure to assess endurance performance among subjects with similar $\dot{V}O_{2max}$ (22). Maybe in elderly particularly, where submaximal endurance could reflect daily living activities in a more consistent way. An improved work economy would increase endurance performance by allowing a runner to run at a higher pace over a given distance, or longer at a constant speed

(23). Moreover, an improved work economy in elderly could lead to lower the oxygen cost during functional tasks, which in turn could lead to a higher degree of independency in this population. Interestingly, studies that have investigated traditional strength training upon work economy in healthy elderly, have failed to observe decreased $\dot{V}O_2$ while walking (20, 24, 25).

Several factors following strength training are associated with improvements in work economy, and few studies have investigated this in elderly. Therefore, it is still of interest to further investigate the effect of adaptations from strength training upon work economy in elderly men. Thus, the aim of the present study was to investigate if alteration in muscle strength or muscle mass was followed by changes in work economy when walking horizontally and uphill, following 12 weeks periodized strength training. We hypothesized that periodized strength training would improve work economy in elderly men. Further, we hypothesized that alterations in muscle strength and muscle mass was followed by changes in work economy.

Methods

Participants

Elderly males (60 – 81 years) were recruited through advertising, from the local community in Kristiansand, Norway. Exclusion criteria were any overt disease or medication, which could influence the tests, or supplements that could interfere with the results. Moreover, none of the participants should have conducted systematic strength training the last 6 months before entering the study. 71 participants were invited to participate in the present study. Sixteen of the participants did not meet the requirements (COPD, cancer, heart failure etc.) set by responsible physician after a medical screening at Sørlandet Hospital Kristiansand, and were excluded. Two participants decided to drop out before the intervention because of personal circumstances. Of the remaining 53, three more participants dropped out during the intervention due to injuries. Seventeen participants were excluded from analyses in the work economy test because of high values in blood lactate (> 2.2 mmol·L^{-1}). Subsequently, 33 older men were included in the analyses. The study complied with the standards set by the Declaration of Helsinki and was approved by the regional committee for medical and health research ethics; south-east before initiation. All subjects were given a written informed consent they signed, before entering the study.

Design

The present study was an extension of “Smartfish, Antioxidants, Recovery and Adaptation” (SARA), with the aim of investigating how high dosage with antioxidants and a Smartfish drink affected adaptations to strength training and endurance exercise in young to middle aged subjects, and in elderly (Paulsen et al, manuscript in preparation). The present study was limited to investigate the effect of 12 week strength training intervention upon work economy in elderly men. Both pre and post testing was supervised by the same test leader. The testing was conducted over three separate days; (1) Sørlandet Hospital Kristiansand for DXA (dual-energy X-ray absorptiometry), (2) 1RM (one repetition maximum), and (3) multiple measurements in following order: Blood sample, Inbody (Bioelectrical Impedance Analysis Method), questionnaire, ultrasound and work economy. A four-day diary registration was carried out to assess their energy intake (26). Daily physical activity was recorded for four consecutive days with the activity monitor SenseWear Pro$_3$ Armband (BodyMedia, US), both pre and after 10 weeks of the intervention. Subjects were instructed to maintain usual food and physical activity habits.

Training protocol

All subjects started with 2 weeks familiarization, which focused on proper exercise techniques, as well as familiarization to the 1RM tests. After the familiarization, 12 weeks of strength training were conducted with an undulating periodized profile (27). The protocol included 3 full-body sessions, with both multi- and single-joint exercises. Two of the sessions each week were “moderate” (8-10 RM, with 1 minute rest between sets), and the third varied between “heavy” (3-5 RM, with 2 minutes rest between sets) and “light” (13-15 RM, with 45 seconds rest between sets)” every second week. The number of sets per exercise increased progressively from 1 to 4 sets during the first 10 weeks, and then reduced with 1 set each of the last 2 weeks of the intervention. All subjects received an individual exercise diary before each session, with individual training load for every exercise. Resistance was weekly adjusted. To ensure proper techniques and to avoid injuries, all training sessions were supervised by qualified instructors.

Work economy

Work economy was measured while walking on a motor driven treadmill (Woodway ELG55, Weil am Rhein, Germany), for a total of 20 minutes. Before the test, height and weight was measured with Inbody 720 (Direct Segmental Multi-frequency Bioelectrical Impedance Analysis Method, BioSpace Co., Ltd., Seoul, South-Korea), and the participants were equipped with heart rate (HR) monitor (Polar S610i, Polar Electro OY, Kempele, Finland). Equipment was calibrated according to instructions from manufacturer every 3rd test, and was repeated until the difference between consecutive calibrations was less than 1%. After a warm up of 5 minutes, the participants walked 5 minutes at three different inclinations: 0%, 4% and 8%. Oxygen consumption ($\dot{V}O_2$) was measured in 30 seconds intervals (Oxycon, Jaeger BeNeLux Bv, Breda, Netherlands). In addition, blood lactate (La^-), respiratory gas exchange ratio (RER) and minute ventilation (V_E) was obtained the last two minutes at each work load.

Blood lactate was collected after each work load with Arcray Lactate Pro LT-1710 (Arkay Inc. Kyoto, Japan).

Dual-energy X-ray absorptiometry

Body composition measured by one experienced observer was assessed by dual-energy X-ray absorptiometry (DXA; GE-Lunar Prodigy, Madison, WI, USA). Participants were scanned from head to toe in supine position, providing values for bone mineral content (BMC), non-bone lean tissue, and fat mass in total body, as well as in arms, legs and trunk separately. Test-retest analyses from 62 scans in 31 participants demonstrated intra class correlation of 0.99 (all with $p < 0.001$) for percentage of body fat, fat mass and lean mass. Limits of agreement (mean differences ± 1.96 standard deviations (SD) of the differences) were -0.3 ± 2.14% for percentage of body fat, -0.26 ± 1.64 for fat mass and -0.23 ± 1.75 kg for lean mass, with 97% - 100% of the values within two SD.

Ultrasound measurements

A single, previously trained examiner performed all of the ultrasound measurements. The muscle thickness was measured in vastus lateralis and rectus femoris using a brightness mode (B-mode) ultrasonographic apparatus (LogicScan 128 CEXT-1Z kit, Telemed, LT), with linear probe of 40mm width and an excitation frequency of 9 MHz. Muscles in the dominant arm or foot were analyzed. The vertical diameter of vastus lateralis and rectus femoris were measured at a distance equal to 40% of the femur length, distally. Scan locations for vastus lateralis and rectus femoris were located between the lateral epicondylus and the great trochanter major of the femur. The images where analyzed with the program ImageJ (version 1.46r, National Institutes of health, USA) widely used for this purpose (28, 29). Test-retest analyses from 20 scans in 10 subjects demonstrated intra class correlation from 0.98 to 0.99 (all with $p < 0.001$) for muscle thickness in rectus femoris and vastus lateralis. Limits of agreements were 0.1 ± 0.6 mm for muscle thickness in rectus femoris, and 0.6 ± 1.1 mm for muscle thickness in vastus lateralis.

Strength testing

Leg extension, scott curl and leg press (All TechnoGym, Italy), was assessed to measure 1RM (one repetition of maximum) pre and post the intervention. The warm-up consisted of four sets with gradual increasing load and descending repetitions; (10 reps at 40-50% of 1RM, 6 repetitions at 60-70% of 1RM, 3 repetitions at 80-90% of 1RM, and 1 repetition at 95% 1RM). After the warm-up, the participants had four attempts on each exercise, where the first attempt was customized to around 5% under expected 1RM after the familiarization. After the first attempt the load was increased until maximum was found, and lift was accepted. The rest interval between each warm-up set was 2 minutes, and 30 to 60 seconds between each leg/arm. When attempting for 1RM, the rest period was for a minimum 2 minutes. Participants were verbally encouraged at each attempt. A more detailed description of the 1 RM exercises has been published elsewhere (30).

Statistics

All statistical analyzes were performed with SPSS Statistics 19.0 (Statistical Product and Service Solutions, Chicago, IL, 2010). Subject characteristics and body composition are reported as mean and SD. Body composition pre and post was measured with paired samples t-test. Due to non-normality, non-parametric tests were used when analyzing muscle strength, muscle mass, muscle thickness and work economy. Wilcoxon’s two-related-samples test was used to compare variables before (Pre) and after (Post) the 12 week strength training intervention. Spearman’s correlations coefficient was used for determine the relationship between the measured variables. All results are presented as median and 95% confidence intervals (CI) if not other is stated. Variables were considered significantly when $p < 0.05$.

Results

The 33 elderly males (68.0 ± 6.1 years, 80.9 ± 11.6 kg) completing the 12 week strength training intervention in the present study succeeded a mean of 33.4 sessions out of a total of 35 sessions (95.4%). Average body mass index at baseline was 25.9 ± 5.1 kg/m^2, and moderate to vigorous physical activity was 2.2 ± 1.4 hours/day (table 1). Observed changes in body composition after the 12 week strength training intervention are presented in table 2. Body mass increased significantly ($p = 0.005$). Following the increase in body mass, a significant ($p < 0.001$) increase was observed in lean mass. No change was observed in fat mass; however, a significant ($p = 0.05$) decrease in body fat % was observed after the 12 weeks strength training.

A significant increase was observed in both muscle strength and muscle thickness (table 3) after the 12 week strength training. Muscle strength increased significantly in both 1RM leg exercises ($p < 0.001$). Leg extension increased by 16.3% (13.8, 21.2) (median and 95% CI), and leg press increased with 18.2% (14.5, 21.4). A significant increase in muscle strength was accompanied with increased muscle thickness. Vastus lateralis increased by 7.2% (5.6, 11.2) and in rectus femoris by 12.1% (8.4, 15.6), both significant ($p < 0.001$).

Significant changes occurred after the strength training during the submaximal endurance test (table 4). The participants significantly improved their work economy, defined as body mass adjusted oxygen consumption (figure 1), at the three different workloads by, respectively, 4.0% (0.3, 7.4) ($p = 0.01$), 2.8% (-1.4, 7.1) ($p = 0.016$) and 2.5% (-0.2, 5.0) ($p < 0.006$). However, not adjusted for body mass ($L \cdot min^{-1}$), an improvement of 3.2% was observed when walking without inclination (0.6, 5.7; $p = 0.012$). At inclinations of 4% and 8%, observed improvements was 2.1% (-1.2, 4.6) and 1.3% (-2.0, 3.2), although not significant. No significantly change in RER or La^- occurred at any inclination. A significant decrease of 5.7% (0, 10.3) (p = 0,007) in V_E was observed when walking horizontally only. The HR decreased significantly at all inclinations, with respectively 3.4% (-1.4, 6.7) (p = 0.041), 3.7% (0.7, 5.5) (p = 0.003) and 3.7% (1.8, 6.6) (p = 0.001).

No significant associations were found between changes in muscle strength or lean mass upon work economy. However, changes in muscle thickness for rectus femoris were significantly negatively associated (r = -0.425; p = 0.014) with work economy at the steepest inclination (8%). Further, significant association between muscle thickness of vastus lateralis and work economy were not observed following 12 weeks of strength training.

Discussion

The primary finding in the present study was that12 weeks of strength training improved work economy during level treadmill walking in elderly men. Work economy also improved during uphill walking, but, only when adjusted for body mass ($mL \cdot kg^{-1} \cdot min^{-1}$). Minute ventilation ($V_E$) decreased during level walking, while heart rate was reduced at each work load from pre to post. No changes were observed in blood lactate or RER. Maximal strength, muscle thickness and muscle mass increased significantly, but changes in muscle strength and lean mass were not associated with changes in work economy. Surprisingly, muscle thickness in vastus lateralis was negatively associated with work economy (r = -0.425; p = 0.014) at 8% inclination.

Adaptations from strength training alone on work economy in elderly have not been widely investigated; however, some studies including elderly individuals have failed to observe an improved work economy during submaximal walking (20, 24, 25). A study by Romero-

Arenas et al. (24) compared 12 weeks of traditional strength training (6RM, 3 minutes rest between sets), with high resistance circuit training (6RM, 30 seconds rest between sets) in untrained elderly participants (61.3 ± 5.3 years). Increased muscle mass (traditional strength; 2.2%, and high resistance circuit; 3.4%) was similar to the 3% increase lean mass in the present study. Moreover, isokinetic strength increased by 20-46% in leg extension/flexion in both groups, also similar to the increased strength in the present study (8-42%). Work economy defined as decreased $\dot{V}O_{2\ LM}$ (i.e. oxygen consumption relative to lean mass), significantly improved in the high resistance circuit group, during an incremental treadmill protocol. $\dot{V}O_{2\ LM}$ decreased by 14.2% while walking flat, and by 16.1% while walking at 3.2° incline. No significant change in $\dot{V}O_{2\ LM}$ was observed in the traditional training group. In the present study, median $\dot{V}O_{2\ LM}$ significantly improved 3.5%, 4.0% and 4.8% when walking at 0%, 4% and 8%, respectively. Further, Hartman et al. (20) failed to observe a significant decrease in $\dot{V}O_2$ during a submaximal walk without inclination at 4.8 $km \cdot h^{-1}$ for 4 minutes, following 26 weeks of traditional strength training, even though a significant increase was observed in fat-free mass (4%), and 1 RM strength (Smith machine squat; 79.1%). However, a significant reduction in $\dot{V}O_2$ walking while carrying a load was found following the 26 weeks of strength training. The finding by Hartman et al. (20), the reduced $\dot{V}O2$ in a functional task, reflects functionality similar to what could be expected in the present study. Both level walking and walking while carrying a load was also measured in the study by Parker et al. (25), following 16 weeks of strength training in elderly women. Despite significant increases in 1 RM strength (leg press; 61.9% and leg extension; 40.4%), no changes was observed in $\dot{V}O_2$ for either submaximal walking or walking while carrying a load.

Several considerations should be mentioned when comparing the results in the present study with other studies. Training volume, intensity, rest period between sets, supervised strength training and baseline levels may all contribute to affect adaptations following strength training (8). When measuring submaximal walking, two of these studies used only level walking (20, 25). Contrary, work economy at inclinations of 0%, 4% and 8% was assessed for 5 minutes stages in the present study. In the study by Romero-Arenas et al. (24) a similar incremental treadmill protocol was used, assessing oxygen consumption during different inclinations. However, only during 2 minutes stages, which could lead to difficulties reaching steady state measures (31). Romero-Arenas et al. (24) found that 30 seconds intervals between sets and exercises resulted in greater improvements in work economy compared to the more traditional 3 minutes. In addition, muscle strength and muscle mass was similar between the high resistance circuit group and traditional strength training group, suggesting that other factors than muscle strength and muscle mass are responsible for the improved work economy. In the study by Parker et al. (25) and Hartman et al. (20), training intensity ranged from 65-80% of 1 RM. As proposed by Steele et al. (32) in their review, high intensity muscular contraction (i.e. repetitions performed to failure) is likely a key factor in strength training with the intention of improving cardiovascular fitness following strength training. The present study was designed with an undulating periodized protocol, with the intention to maximize increases in muscle mass. Thus, the increased leg strength (leg extension; 16.3% and leg press; 18.2%) was not only a results of neural adaptation, whereas lean mass increased 3%, and measured muscle thickness in vastus lateralis and rectus femoris increased with 7.2% and 12.1%, respectively. However, the strength training was performed until failure in all exercises, possible leading to the observed improvements in work economy. Moreover, the relative short rest periods between sets in both light sessions (45 seconds) and moderate sessions (1 minute) in the present study, would possible increase the aerobic capacity more than traditional strength training with longer rest periods between sets.

In some way favorable changes occurred in body composition following the 12 weeks strength training. Even though body mass increased 1.3%, no changes was found in fat mass. Increased body mass was accompanied by an increased lean mass by 3%, and thus and decrease in percentage of body fat. The improvements in work economy were respectively 4.0%, 2.8% and 2.5% during level walking and at 4% and 8% inclination. However, no significant changes in work economy were observed between the different workloads. Even though leg strength has been shown to correlate with endurance performance (19, 21) in previous studies, no significant association was found between muscle strength and work economy in the present study. However, muscle thickness in vastus lateralis was negatively associated with work economy. This suggests that together with the observed increase in body mass, which were followed by increased lean mass and muscle thickness could reduce the oxidative capacity in the working muscles. In addition, increased body mass could affect work economy, as observed with the decreasing improvements in work economy with steeper inclination.

The mechanisms behind improved endurance performance and work economy following strength training still seem to be unclear. Several mechanisms may contribute to improved work economy and endurance capacity, and some of them are likely to be affected with aging (33). Adaptations from strength training may result in maintenance of or increased capillary density and increased mitochondrial content and oxidative capacity (34). Both endurance and resistance training is likely to transform type IIx fibers into more fatigue resistant type IIa fibers (35). Moreover, strength training may lead to increased tendon stiffness, which improves the muscle-tendon system's ability to store and release elastic energy during locomotion (36). Thus, strength training seems to stimulate peripheral adaptations which are generally associated with aerobic training, and may improve similar adaptations leading to improved aerobic capacity, work economy, and ultimately endurance capacity. Responsible mechanisms behind adaptations from strength training upon work economy remain to be completely elucidated. Since both endurance and strength in elderly are necessary for functionality (1), and are predictors of mortality (37, 38), knowing how to improve these factors seems essential. In turn could these adaptations be beneficial for long-term health and quality of life in elderly. Future research should investigate the underlying mechanisms resulting to an improved work economy in this age group.

The main *strength* of the present study are the objective and reliable measurements of oxygen consumption (39), body composition (40), muscle thickness with ultrasound (29) and the 1 RM strength testing (41). The attendance was high (95.4%), and together with close follow-up of the participants, no voluntary drop outs were observed during the intervention. Several *limitations* should be mentioned in the present study. First of all, the lack of a control group limits the ability to conclude that the observed improvement in work economy, exclusively came from the strength training intervention, and was not a learning effect. Second, we ruled out elderly with physical injuries or use of medication to participate in the present study. Thus, only healthy physical active elderly aged 60 to 81 years were included. Results may be different in elderly with other characteristics. In the present study, all participants underwent an undulating periodized strength training protocol, making it difficult to determine what strength regimen being responsible for the improved work economy. *In summary*, following 12 weeks of periodized strength training, the elderly participants improved muscle strength, lean mass and work economy. Thus, it seems to be a surprising degree of overlap between resistance and endurance training. Data from the present study suggests that other factors then muscle strength and lean mass are responsible for the mechanisms behind the improved work economy. The findings in the present study are important and relevant for elderly wanting counterattack age related declines in physical function.

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Table and figure legends

Table 1.

Subject characteristics (n=33). All values are mean ± SD.

Table 2.

Body composition changes before (Pre) and after (Post) the 12 week strength training intervention (n=33). All values are mean ± SD. * Significant different from pre-training ($p<0.05$).

Table 3.

Muscle strength in leg press and leg extension and muscle thickness in vastus lateralis and rectus femoris before (Pre) and after (Post) the 12 week intervention period. * Significant lower than pre values ($p < 0.001$). All values are median and 95% CI.

Table 4.

Oxygen consumption (VO_2), heart rate (HR), blood lactate conscentration (La^-), ventilation (V_E) and respiratory gas exchange ratio (RER) during the work economy test at 0%, 4% and 8% inclines with a constant speed of 5 km/h on the treadmill. Values are median and 95% CI. * Significant lower than pre values ($p < 0.05$). Note: n =33, except HR, with respectively n=32, n=30 and n=31 at 0%, 4% and 8% inclination.

Figure 1.

Work economy ($\dot{V}O_{2)}$ before (Pre) and after (Post) the 12 week strength training intervention period. Values are mean and 95% CI.

Table 1

Subject Characteristics	**Mean ± SD**
Age (years)	68.0 ± 6.1
Height (cm)	177.5 ± 5.9
Weight (kg)	80.9 ± 11.6
Body mass index (kg/m^2)	25.9 ± 5.1
Moderate-vigorous PA (hours/day)	2.2 ± 1.4

Table 2

Body composition			
	Pre	**Post**	**% Change**
Body mass (kg)	80.9 ± 11.6	81.9 ± 11.4 *	1.3 % ± 2.4
Fat mass (kg)	20.1 ± 7.3	19.9 ± 7.1	-0.0 % ± 10.1
Lean mass (kg)	57.7 ± 6.1	59.4 ± 6.0 *	3.0 % ± 2.5
BodyFat (%)	25.2 ± 6.2	24.5 ± 6.0 *	-2.1 % ± 8.4

Table 3

Muscle strength and muscle thickness

	Pre	**Post**
Leg press	300 (280, 330)	360 (330, 390) *
Leg extension	85 (72.5, 92.5)	100 (87.5, 107.5) *
Vastus lateralis	23.6 (21.5, 25,0)	25.0 (22.9, 26.5) *
Rectus femoris	18.0 (17.4, 18.8)	20.2 (19.1, 21.4) *

Table 4

	0 %		**4 %**		**8 %**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
$\dot{V}O_2$ (mL·kg^{-1}·min^{-1})	14.1 (13.4, 14.8)	13.7 (13.2, 14.3)*	17.2 (16.6, 18.2)	17.0 (16.6, 17.6)*	21.6 (20.9, 22.7)	21.4 (20.8, 21.8)*
$\dot{V}O_2$ (L·min^{-1})	1.15 (1.06, 1.22)	1.11 (1.04, 1.17)*	1.42 (1.33, 1.52)	1.43 (1.29, 1.45)	1.74 (1.66, 1.91)	1.77 (1.63, 1.85)
HR (beats min $^{-1}$)	90 (84, 93)	88 (77, 92)*	99 (92, 102)	94 (85, 101)*	108 (104, 123)	107 (98, 115)*
La^- (mmol)	0.9 (0.8, 1.2)	1.0 (0.8, 1.3)	0.9 (0.8, 1.1)	1.1 (0.9, 1.3)	1.3 (1.1, 1.6)	1.2 (1.1, 1.4)
V_E (L·min^{-1})	32 (31, 34)	31 (29, 33)*	39 (35, 41)	37 (35, 40)	48 (43, 52)	48 (43, 52)
RER	0.9 (0.88, 0.92)	0.89 (0.87, 0.92)	0.9 (0.89, 0.91)	0.9 (0.87, 0.92)	0.93 (0.9, 0.94)	0.93 (0.91, 0.94)

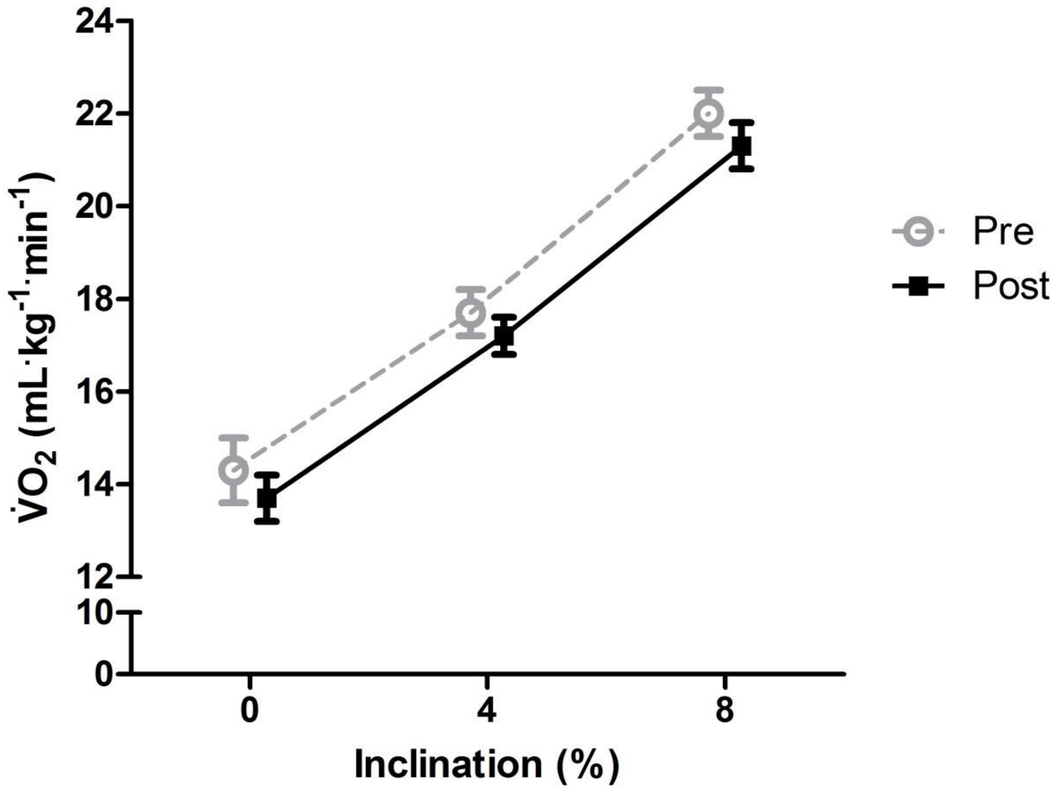
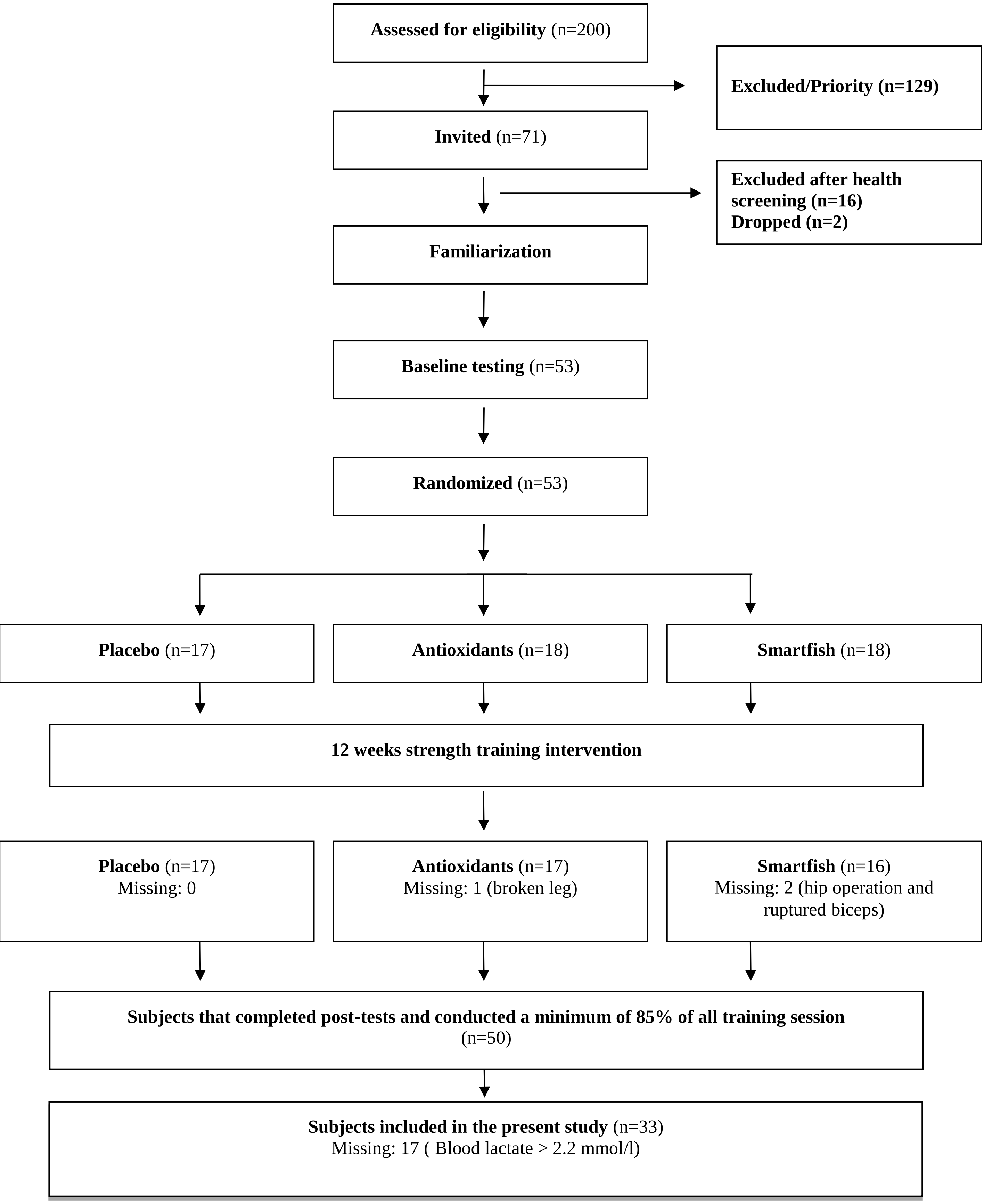

24
22
20
18
16
14
12
10
0
$\dot{V}O_2$ (mL·kg^{-1}·min^{-1})
0
4
8
Inclination (%)
Pre
Post

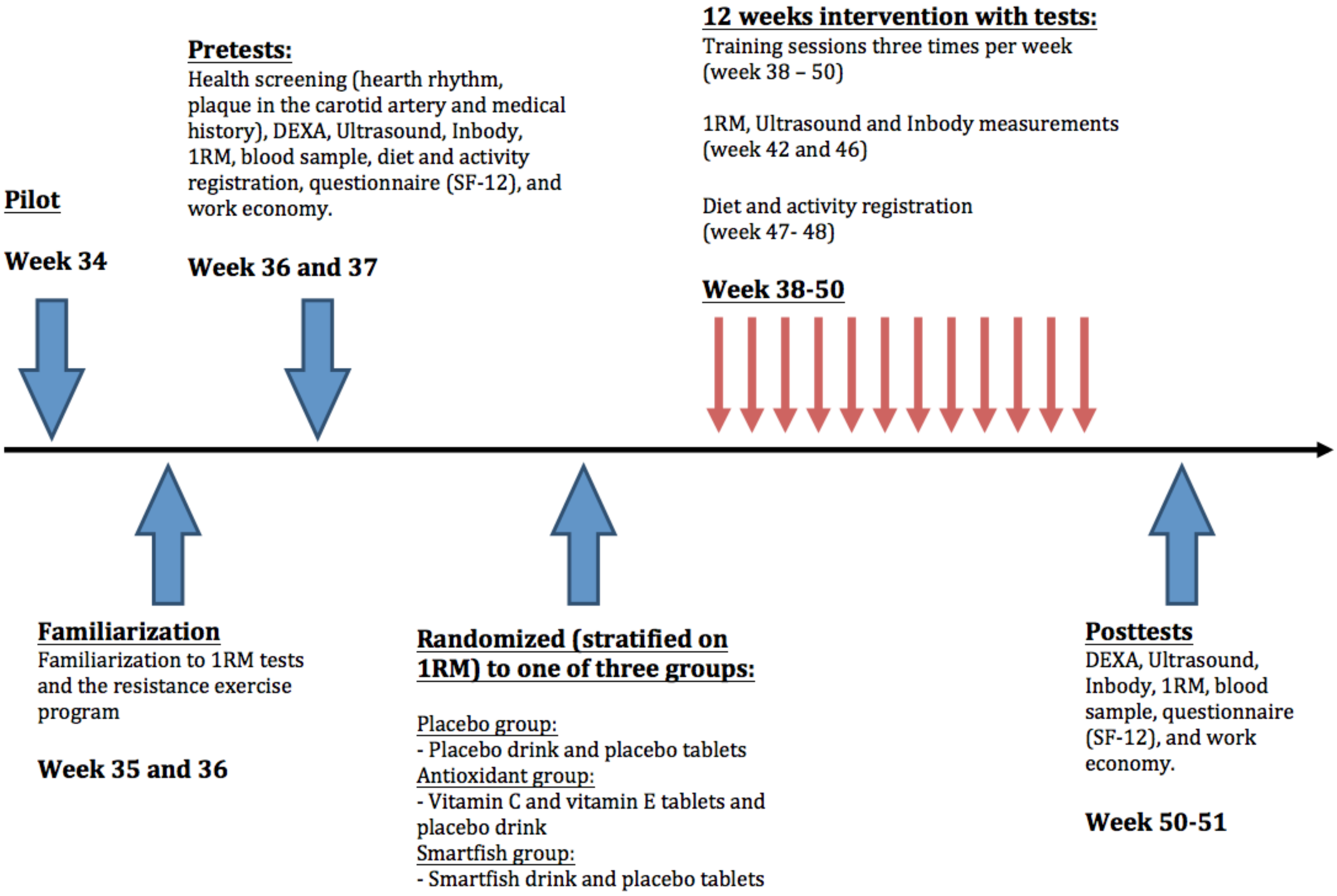
Figure 1

Appendix 1



Flow-chart showing inclusion and exclusion of participants in the present study.

Appendix 2



Timeline - design of the SARA-elderly study, with illustration of the different aspects investigated.

Appendix 3

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Tor Even Svanes	22845521	12.06.2012	2010/1352

Deres dato:	Deres referanse:
22.05.2012	

Vår referanse må oppgis ved alle henvendelser

Gøran Paulsen

Norges Idrettshøyskole

Postboks 4014

Ullevål Stadion 0806 Oslo

2010/1352 Hvordan påvirker antioksidanttilskudd treningseffekt

Forskningsansvarlig: Norges Idrettshøyskole

Prosjektleder: Gøran Paulsen

Vi viser til søknad om prosjektendring datert 22.05.2012 for ovennevnte forskningsprosjekt. Søknaden er behandlet av leder for REK sør-øst på fullmakt, med hjemmel i helseforskningsloven § 11.

Endringen består i at man ønsker å legge til to studiegrupper i prosjektet. Den første gruppen vil være på ca. 60 deltakere i alderen 60-80 år, som vil inngå i styrketreningsarmen av studien. Den andre gruppen vil være på ca. 40 utrente deltakere, som vil inngå i utholdenhetstreningsarmen av studien. Det vil ikke tas muskelbiopsi fra disse kohortene. Prosjektendringen består videre av en utvidelse av prosjektperioden, frem til 2013. Sveinung Berntsen ved Universitetet i Agder går inn i studien som prosjektmedarbeider.

Formålet med endringen er å se på effekten av antioksidanttilskudd i mer differensierte grupper enn det som allerede er inkludert i studien.

Komiteen har ingen forskningsetiske innvendinger til selve designet i den utvidede delen av studien, og registrerer at det blant annet anføres rutiner for klinisk screening av deltakerne før inklusjon som en del av endringsprotokollen. Komiteen legger derfor til grunn at det finnes klare og gode beredskapsrutiner i forsøkene, da det nå skal inkluderes både eldre og mindre trente personer til prosjektet.

Vedtak

Prosjektendringen godkjennes.

Tillatelsen er gitt under forutsetning av at prosjektendringen gjennomføres slik det er beskrevet i prosjektendringsmeldingen og endringsprotokoll, og de bestemmelser som følger av helseforskningsloven med forskrifter.

Tillatelsen gjelder til 31.12.2013. Opplysningene skal deretter slettes eller anonymiseres, senest innen et halvt år fra denne dato. Prosjektet skal sende sluttmelding på eget skjema, jf. helseforskningsloven § 12, senest et halvt år etter prosjektslutt.

Klageadgang

Du kan klage på komiteens vedtak, jf. forvaltningslovens § 28 flg. Klagen sendes til REK sør-øst. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK sør-øst, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Med vennlig hilsen

Arvid Heiberg

prof. dr.med

leder REK sør-øst C

Kopi til: *Norges Idrettshøyskole v/Tom Atle Bakke: tom.atle.bakke@nih.no*

Tor Even Svanes seniorrådgiver

Appendix 4

Forespørsel om deltakelse i forskningsprosjektet: Hvordan påvirker antioksidanttilskudd effekt av styrketrening på eldre?

Bakgrunn og hensikt
Antioksidanter, både de produsert av cellene selv og de vi får via maten vi spiser (f.eks. vitamin C og E), er viktige for at kroppens celler skal fungere og være motstandsdyktige mot ulike former for stress. Ved aldring kan det oppstå en tilstand av vedvarende stress i cellene. Dette kan motvirkes med både trening og kanskje ved økt inntak av antioksidanter. Denne studien har til hensikt å undersøke kombinasjonen av styrketrening og antioksidanttilskudd, samt effekten av styrketrening og Smartfish-drikk. Smartfish har lagd et produkt som inneholder spesielt ferske, marine fettsyrer, samt naturlige antioksidanter fra frukt-juice (se http://www.smartfish.no/).

Er du en frisk mann mellom 60 og 80 år og bedriver ikke regelmessig styrketrening, kan du delta som forsøksperson i denne studien.

Denne studien er et samarbeidsprosjekt mellom Norges idrettshøgskole (Oslo), Universitet i Agder (Kristiansand) og Sørlandet sykehus (SSHF).

Hva innebærer prosjektet?
Dette er et dobbelt blindet, randomisert, kontrollert studie, som betyr at verken du eller forskerne du kommer i kontakt med vet om du inntar vitamin C og E, Smartfish eller placebo (”lure-drikk/-piller”). Du vil innta drikken og piller før og etter trening, samt morgen og kveld de dagene du ikke trener.

I de første ukene av prosjektet vil vi måle din fysiske styrke, muskeltykkelse i lår og armer (v.h.a. et ultralydapparat) og total muskelmasse (v.h.a. en DXA-maskin som sender ut to røntgenstråler). Det vil tas en blodprøve og kondisjonen din testes på en tredemølle. Du vil også gjennomgå en legesjekk, som inkluderer undersøkelser av hjertet. Kostholdsregistrering og aktivitetsregistrering vil også bli gjennomført. Tester og undersøkelser gjøres ved Spicheren (ved Universitet i Agder) og Sørlandet Sykehus.

Først etter at alle tester og undersøkelser er gjennomført, vil du bli tilfeldig valgt til en av de tre gruppene, innlæringsøkter gjennomføres, og du vil begynne på treningsprogrammet. Du skal trene 3 økter per uke. Treningsperioden varer i 12 uker (40 økter). Styrketreningen består av tradisjonelle øvelser for hele kroppen. Under hver trening skriver du ned hva du gjør (hvor tunge vekter du benytter etc.). Du vil få god veiledning på starten av treningsprogrammet, slik at du lærer deg alle øvelsene godt, og du vil få tett oppfølging underveis i treningsperioden. Det vil være faste tider du kommer og trener sammen med andre deltakere.

Underveis i treningsperioden vil vi gjenta noen av styrketestene og måle muskeltykkelsen din. Etter treningsperioden vil alle testene og undersøkelser gjentas.

Mulige fordeler og ulemper ved å delta i prosjektet

Fordeler:

- Du får en gratis legesjekk.
- Du får bl.a. målt og testet styrken og muskelmassen din.
- Du vil følge et treningsprogram som er laget for at du skal bli sterkere, komme i bedre form og få bedre helse. Du vil få kyndig oppfølging under hele treningsperioden.

Ulemper:

- Du vil bruke tid på tester, undersøkelser og trening.
- Vekttrening medfører risiko for skader. Risikoen for skader anses som lav.
- Noen tester og undersøkelser kan oppleves som anstrengende og ubehagelige.
- Målingen av muskelmassen gir en liten stråledose (tilsvarende en interkontinental flyreise).
- Blodprøver fra en vene i albueområdet kan oppleves som ubehagelig, og det medfører en risiko for infeksjoner. Risikoen for infeksjoner anses som svært lav.

Hva skjer med prøvene og informasjonen om deg?

Alle i prosjektet oppgir sitt navn og telefonnummer. Deretter får alle et unikt nummer som skrives opp ved navnet på navnelisten. Denne listen oppbesvares nedlåst i arkivskap godkjent for oppbevaring av personopplysninger. Resultatene fra tester og undersøkelser påføres kun nummeret ditt. Når prosjektet er ferdig slettes navnelisten. Dataene vil da være helt anonyme.

Statens legemiddelverk og kontrollmyndigheter i inn- og utland kan få utlevert studieopplysninger og gis innsyn i relevante deler av din journal. Formålet er å kontrollere at studieopplysningene stemmer overens med tilsvarende opplysninger i din journal. Alle som får innsyn i informasjon om deg har taushetsplikt.

Frivillig deltakelse

Det er frivillig å delta i prosjektet. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke til å delta, uten at dette vil få noen negative konsekvenser for deg. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side.

Etikk

Prosjektet har vært fremlagt for Regional komité for medisinsk og helsefaglig forskningsetikk, helseregion sør-øst, som har godkjent prosjektet. Studien er også godkjent av legemiddelverket.

Kontaktinformasjon

Dersom du senere ønsker å trekke deg eller har spørsmål om prosjektet kan du kontakte personene på listen under. Dersom du mener du er påført en skade av deltakelse i prosjektet kan du også henvende deg til personene under som da vil sørge for at du får hjelp/behandling for dette:

Svein Salvesen	svein.salvesen47@gmail.com	47 64 23 99
Thomas Bjørnsen	thomas.bjornsen@hotmail.com	98 61 92 99

Ytterligere informasjon om studien finnes i kapittel ***A*** *– utdypende forklaring av hva studien innebærer.*
Ytterligere informasjon om biobank, personvern og forsikring finnes i kapittel B *– Personvern, biobank, økonomi og forsikring.*

Samtykkeerklæring for underskrift følger etter kapittel B.

Kapittel A- utdypende forklaring av hva studien innebærer

Kriterier for deltakelse

- Alder: 60-80 år
- Kjønn: Mann
- Har ikke drevet systematisk styrketrening de siste 6 mnd. (trening med vekter).
- Ingen kjente sykdommer eller medisinbruk som kan påvirke treningseffekten (ta kontakt om du er usikker på hva dette innebærer).
- Inntar ingen former for kosttilskudd ved prosjektstart.

Tidsskjema – hva skjer og når skjer det?

- Tester av muskelmasse og styrke gjennomføres samt utfylling av spørreskjema gjennomføres første gang i august-september 2012, og andre og siste gang desember 2012.
- Treningsperioden er fra august-september til november-desember 2012.

Mulige fordeler

- Se ovenfor

Mulige bivirkninger

- Se ovenfor

Mulige ubehag/ulemper

- Se ovenfor

Pasientens/studiedeltakerens ansvar

- Å komme til avtalt tid for testing og undersøkelser, samt følge treningsopplegget og innta supplementene.

Kapittel B - Personvern, biobank, økonomi og forsikring

Personvern

Opplysninger som registreres om deg er

- Alder
- Telefonnummer
- Kjønn
- Høyde
- Vekt
- Muskelmasse og -styrke
- Treningshyppighet og varighet (treningsdagbok)

Norges idrettshøgskole ved administrerende direktør er databehandlingsansvarlig.

Biobank

Blodprøvene som blir tatt og informasjonen utledet av dette materialet vil bli lagret i en forskningsbiobank ved Universitetet i Agder. Hvis du sier ja til å delta, gir du også samtykke til at det biologiske materialet og analyseresultater inngår i biobanken. Professor Truls Raastad ved Norges idrettshøgskole er ansvarshavende for forskningsbiobanken. Biobanken planlegges å vare til 2023. Etter dette vil materiale og opplysninger bli destruert og slettet etter interne retningslinjer.

Utlevering av materiale og opplysninger til andre

Nei.

Rett til innsyn og sletting av opplysninger om deg og sletting av prøver

Hvis du sier ja til å delta i studien, har du rett til å få innsyn i hvilke opplysninger som er registrert om deg. Du har videre rett til å få korrigert eventuelle feil i de opplysningene vi har registrert. Dersom du trekker deg fra studien, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser, er brukt i vitenskapelige publikasjoner eller om informasjonen er anonymisert (etter at navnelisten er slettet)

Økonomi

Studien er finansiert av midler fra Norges idrettshøgskole, Universitetet i Agder, Smartfish, SSHF og regionalt forskningsfond i Agder.

Forsikring

Norges idrettshøgskole er en statlig institusjon og er således selvassurandør.

Informasjon om utfallet av studien

Forsøkspersoner får utlevert egne resultater og det vil avholdes et informasjonsmøte for forsøkspersonene i etterkant av undersøkelsen. Resultatene fra alle forsøkspersonene vil bli publisert i internasjonale, fagfellevurderte tidsskrift. Resultatene publiseres som gjennomsnitt for flere personer, og det vil ikke være mulig å identifisere enkeltdeltakere gjennom de publiserte resultatene.

Samtykke til deltakelse i studien

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 5

UNIVERSITETET I AGDER

Invitasjon til trenings- og forskningsprosjekt ved Universitetet i Agder:

MANN 60 - 80 ÅR SOM VIL BLI STERK?

Vil du være med, øk muskelmassen din og bli sterk, samtidig som du har det moro i et treningsmiljø under veiledning av fagfolk med høy kompetanse! (alt er gratis)
Hvis svaret er JA, og du oppfyller kriteriene nedenfor, er du aktuell deltaker for et trenings- og forskningsprosjekt ved Universitetet i Agder, Fakultet for helse- og idrettsfag.

Kriterier

- Vi søker menn mellom 60 – 80 år
- Du må ikke ha trent regelmessig styrketrening de siste 6 måneder før studien starter (oppstart medio august)

Trening/testing:

Treningen foregår tre ganger i uken over 12 uker i eget lokale på Spicheren Treningssenter og muskelstyrke testes i forkant og etterkant av denne tidsperioden. Styrketrening blir av veldig mange eksperter ansett som den viktigste treningen for eldre. Samtidig har forskning vist at inntak av antioksidanter har en positiv helseeffekt ved trening. Derfor ønsker vi også å se på en eventuell effekt av antioksidanttilskudd på styrketreningen.

Du inviteres til informasjonsmøte:

Onsdag 08. august 2012 klokken 18:00 i Auditorium B1 007 på Universitetet i Agder (skilt viser veien fra hovedinngangen).

Er det noe du lurer på?

Spørsmål rettes til universitetslektor Ken Joar Hetlelid, tlf. 38 14 21 34 eller epost ken.j.hetlelid@uia.no, eller mastergradsstudenter: Thomas Bjørnsen, mob. 986 19 299, Svein Salvesen, mob. 476 42 399.

Appendix 6

REGISTRERINGSSKJEMA FOR AKTUELLE DELTAKERE

Navn:
Alder:
Telefon:
Mobil:
Adresse:
Personnummer:
E-post:

Har du mulighet for å trene på dagtid (ja/nei)?

Skal du reise bort i løpet av perioden
midten av august til midten av desember (ja/nei)?

Hvor mange dager sammenhengende?

Treningsbakgrunn de siste 6 måneder?

Bruk av medisiner (ja/nei)?
Navn:
For hva:

Røyker daglig?

Kroniske plager som kan begrense deltakelse,
eller ha innvirkning på treningen?

Andre hensyn vedrørende helsestatus?

Vær ærlig for deg selv og ovenfor prosjektet!

Appendix 7

	Session 1	**Session 2**	**Session 3**
1 wk	8-10 rep. **1 (warm-up) + 1** series 1 min rest between set **and exercises**	13-15 rep. 1 + 1 series 45 sec rest between set **and exercises**	3-5 rep. 2 min rest between set **and exercises**
2 wk	**1 (warm-up) + 2** series		1 + 1 series
3 wk	**1 (warm-up) + 2** series	1 + 2 series	
4 wk	**1 (warm-up) + 2** series		1 + 2 series
5 wk	**1 (warm-up) + 3** series	1 + 2 series	
6 wk	**1 (warm-up) + 3** series		1 + 3 series
7-8 wk	**1 (warm-up) + 3** series	1 + 3 series	1 + 3 series
9 wk	**1 (warm-up) + 4** series	1 + 3 series	
10 wk	**1 (warm-up) + 4** series		1 + 4 series
11 wk	**1 (warm-up) + 3** series	1 + 3 series	
12 wk	**1 (warm-up) + 2(3)** series		1 + 2(3) series
		Exercises:	
	Bulgarian squat	"Sumo" deadlift w/ kettlebells	Leg-extension
	Squat	Lunges	Leg press
	Bench-press	Step up	Chest-press
	Pull-down narrow grip	Flyes	Pull-down wide grip
	Upright row	Seated row machine	Arnold-press
	Calf raise	Lateral raises	Bench-press narrow grip
	French press	Triceps pushdown	Scott curl
	Standing biceps curl w/dumbbells	Scott curl	Side-plank
	Quadruped exercise	Plank	

Appendix 8

Dato: Økt: 8-10 reps

Klokkeslett: Pausevarighet: 1 minutt

	Mål	Oppvarming		Sett 1		Sett 2		Sett 3		Sett 4		Omni
Øvelser	Kg	kg	reps	kg	reps	kg	reps	kg	reps	kg	reps	
Bulgarsk knebøy												
Beinpress 2bens												
Benkpress												
Sittende roing												
Opptrekk												
Stående tåhev												
Franskpress												
Scott curl												
Ryggstrekk												