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POWER-TYPE STRENGTH TRAINING IN MIDDLE-AGED MEN AND WOMEN*

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1.Surakka, J., Alanen, E., Aunola, S., Karppi, S-L. and Pekkarinen, H. (2005) Effects of external light loading in power-type strength training on muscle power of the lower extremities in middle-aged subjects. *International Journal of Sports Medicine* (in press).

2. Surakka, J., Alanen, E., Aunola, S. and Karppi, S.L. (2001) Isoresistive dynamometer measurement of trunk muscle velocity at different angular phases of flexion and extension. *Clinical Physiology* **21,** 504–511.

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5. Surakka, J., Alanen, E., Aunola, S., Karppi, S.L. and Lehto, P. (2004) Adherence to a power-type strength training programme in sedentary, middle- aged men and women. *Advances in Physiotherapy* **6,** 99–109.

CONTENTS

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ABSTRACT

Muscle strength declines with increasing age, and the power-type strength characteristics decline even more drastically than the maximal muscle strength. Therefore, it is important to design training programmes specifically for sedentary middle-aged people to effectively improve the power-type strength in leg and trunk muscles. To be suitable for the target group, the exercise programmes should be feasible, motivating and easy to practice. The aim of this study was to design and investigate the effects and feasibility of a power-type strength training programme in 226 middle-aged men and women, with 26 persons as non-training controls. The subjects trained three times a week during 22 weeks, in 12 groups with exercise classes of 10–20 subjects, and using no or very little external equipment. All training sessions were controlled and supervised by an professional instructor. Vertical squat jump, standing long jump, 20 metre running time, maximal anaerobic cycling power, maximal oxygen uptake, and angular trunk muscle flexion and extension velocities were measured before and after the training period to evaluate the training effects. Questionnaires concerning employment, physical activity, smoking, musculoskeletal symptoms and exercise motives were also filled in before and after the training period. The greatest improvements were achieved in vertical squat jump (18%) and in angular trunk flexion (14%) and extension (16%) velocities. An external loading totalling 2.2 kg (attached) in ankles increased the height in vertical squat jump by 23% and maximal anaerobic cycling power by 12%, these improvements were significant compared with subjects in no load training group ($p = 0.03$ in vertical squat jump and $p = 0.05$ in maximal anaerobic cycling power). Exercise induced injuries occurred in 19% of men and 6% of women. Low back symptoms decreased in exercisers by 12% and knee symptoms (increased) by 4% during the intervention. Of all subjects, 24% dropped out during the training period. In summary, improvements were achieved in several physiological performances reflecting the power-type strength qualities, especially in vertical squat jump and trunk muscle flexion and extension velocities. Improved perceived health and fitness among the participants who completed the training programme, and the relatively low number of injuries also indicate the feasibility of the programme. The training programme is simple, and it also seems to be practical among middle-aged, sedentary subjects. It may be useful in preventing the decline of power-type strength characteristics in middle-aged subjects.

KEY WORDS: Adherence, feasibility, middle-aged, power-type strength, training effects, training programme.

1. INTRODUCTION

Muscle power, which is the product of the velocity and force of muscle contraction, is needed for performing daily habitual tasks and activities. Muscle strength declines with advancing age, starting at the beginning of the sixth decade, and the power-type strength, i.e. the capacity to produce explosive muscle force, declines more drastically than the maximal muscle strength (Izquierdo et al., 1999; Anton et al., 2004). Mechanisms contributing to this development may include the loss of Type II fast-twitch motor units (Lexell et al., 1988), or intrinsic changes in muscle force and power production capacity (Frontera et al., 2000). The age-related strength decrease has been previously reported to be faster in lower extremities than in the upper body (Asmunssen and Heeboll-Nielsen, 1962; Bemben et al., 1991). Recently, Anton et al. (2004) demonstrated similar age-related declines both in the arm and leg muscles.

Strength and power-type strength training are recommended for middle-aged and even elderly people for the purpose of maintaining the functional capacity (Häkkinen et al., 1998; Izquierdo et al., 1999; Jozsi et al., 1999). This is important especially with increasing age, in connection with daily activities and even in prevention of falling (Bassey et al., 1992; Skelton et al., 2002). People are commonly engaged in and familiar with endurance training and resistance training. In natural human movements, however, several physiological functions interact simultaneously, and therefore, all the components of muscular performance should be trained equally. It has been suggested (Häkkinen et al., 1998) that strength training in combination with some explosive types of exercises be recommended as a part of overall physical training to maintain the functional capacity in middle-aged and elderly people. For explosive muscle performance, the underlying factors are muscle fibre type, muscle hypertrophy and enzymatic and neural adaptations.

It is also important to investigate the impact of power-type strength training on the low back and knee muscles and joints, as well as the injury risks and adherence and motivation to training. For being effective in improving the explosive muscle performance, training programmes should be designed so as to be motivating, easy to achieve, effective concerning the time spent in exercises, low in expenses, and they should give consideration to the exercise history and present exercise activity, health status and musculoskeletal symptoms and diseases of the individual. Even the socio-economic status and the social and economic environment should be taken into account when evaluating the actual possibilities for completing the planned programme. The exercises should be integrated in everyday life and take place on a regular basis.

Both in physical training and in the rehabilitation of middle-aged people, the endurance type training is commonly used, e.g. walking, jogging, cycling or swimming. The effects of endurance exercises are well known, and various training modes are established and widely adopted by non-athletic people. However, in everyday life the explosive muscle qualities are also needed in various tasks and reactions, e.g. prevention of falls. Training that affects the explosive muscle qualities should therefore not be ignored, especially when it is known that explosive type strength declines with ageing more drastically than maximal muscle strength. However, physical training has been shown to be effective in preventing the decline of muscle power provided that the intensity, duration and frequency of training is sufficient.

For decades, resistance training has been used for the purpose of achieving strength and power, but this type of training needs special training facilities and equipment. The purpose of this study was to find out an alternative method for exercising the explosive muscle characteristics that would use no or very little equipment, be simple and effective, and feasible for middle-aged sedentary people. The programme should also motivate the participant to continued physical activity after the intervention.

2. REVIEW OF THE LITERATURE

2.1. Power-type strength in leg and trunk muscles

Muscle actions are either isometric or dynamic. In isometric actions the muscle length does not change, while dynamic contractions affect the length. Dynamic muscle contractions can further be classified into concentric and eccentric. In concentric contraction the muscle length decreases and in eccentric contraction it increases. Human movement is seldom based on purely isometric, concentric or eccentric muscle contraction. Body segments are periodically organised to impact forces, for instance, in running or jumping, where external forces lengthen the muscle. In these phases, muscles act eccentrically, and the concentric action follows for achieving positive work (Cavagna et al., 1968). A combination of eccentric and concentric muscle actions constitutes what is called stretch shortening cycle (Komi, 1984; Cavanagh, 1988). The eccentric action influences the subsequent concentric phase so that the final contraction is more powerful than a concentric action alone would have been (Komi, 1984). Strength is defined as the maximal amount of force a muscle can generate in a specified movement at a specified movement velocity. The power of muscle contraction is a measure of the total amount of work that a muscle can produce in a given time period. This is determined by the strength of the muscle contraction, by the distance of contraction and the number of contractions in a time period. A performance of daily activities requires both strength and power-type strength, and therefore, muscle conditioning and strength training should be supplemented by exercises with higher velocities. Typical performances requiring explosive power-type strength include various jumps, where the maximal strength level must exceed the load to be moved (i.e. own body). The power-type strength is needed also in high-velocity training requiring acceleration, fast running, and rapid changes of direction (e.g. football, tennis).

Trunk muscles protect the spinal structures against potentially harmful loads and sudden movements (Floyd and Silver, 1955; Troup, 1986). The measurements of trunk muscle velocity, acceleration and torque are important for investigating the stress components of the spine (Beimborn and Morrissey, 1988). Muscle biopsies from diskectomy patients have revealed selective atrophy of fast-twitch fibres in low back muscles (Mattila et al., 1986; Zhu et al., 1989), with physical inactivity presented as one of the possible explanations. Poor trunk muscle function is a potential risk factor for low back disorders (Suzuki and Endo, 1983; Lee et al., 1995).

2.1.1. Measurements in power-type strength training studies

Force production and velocity of the neuromuscular system are the major elements of power-type strength. Vertical jump tests are widely used to evaluate the power-type strength of lower extremities. Measurement of the vertical jumping height is a simple and reliable (reproducibility r =

0.92) method for measuring the explosive force of leg muscles (Bosco et al., 1982; Bosco et al., 1983). The height of vertical jump correlates with 60 m sprint running (Bosco et al., 1983), and also with the maximal power of Wingate cycling test (Maud and Shultz, 1986). Margaria's (Margaria et al., 1966) staircase running test is another simple and reliable test of anaerobic power. Standing long jump has also been widely used in sports research in measuring horizontal explosive force of leg muscles (Bosco et al., 1983; Vandewalle et al., 1987; Manning et al., 1988; Moir et al., 2004). Twenty-metre sprint running is recommended as one of the methods to measure maximal anaerobic performance (Rusko and Nummela, 1996; Moir et al., 2004). Rusko et al. (1993), Rusko and Nummela (1996), and Nummela (1996) developed a method that allows the evaluation of several determinants of maximal anaerobic performance, including the changes in the force of leg muscles and relative to speed in sprint running. Isokinetic knee dynamometers have also been used to test the power of lower extremities (Moffroid et al., 1969; Osternig et al., 1977; Madsen, 1996).

Several studies (Parnianpour et al., 1989; Rytökoski et al., 1994; Hutten and Hermens, 1997) have shown the isoresistive dynamometer measurement of trunk muscle flexion and extension strength and velocity to be reliable and valid.

Perceived health and fitness were assessed by using a five-point Likert scale (poor, fairly poor, average, fairly good, good) that has previously been used by, i.e., Moum, 1992 and Wolinsky and Johnson, 1992. This method has shown to be reliable and consistent with the assessed medical health and its functional consequences (Lundberg and Manderbacka, 1996; Manderbacka, 1998).

Musculoskeletal disorders were inquired about by using the standardised Nordic musculoskeletal questionnaire, which has shown to be a reliable and valid method for that purpose (Kuorinka et al., 1987).

2.1.2. Effects of power-type strength training on leg muscles

Proteins are the major component constituting the contractile apparatus of the muscle. There is a continuous process of protein synthesis and degradation in the body (although the structure of the body is stable). The half-life of proteins determines the rate of adaptation to physical exercise training. The range of variation of the half-life of proteins is from less than one hour to several weeks (Maughan et al., 1997). The contraction velocity of a muscle fibre is determined by the isoform pattern of the contractile proteins. The muscle proteins (i.e myosin heavy chains) Type I, Type IIa and Type IIb are the prime determinants of the muscle contraction velocity. Type I represents the slow and fatigue-resistant muscle contractions, while Type IIa represents the fast, oxidative and fatigue-resistant muscle contractions and Type IIb the fast, fatigable muscle contractions (Staron, 1997). Upon initiation of training, changes in the types of muscle proteins begin to take effect within a couple of training sessions (Staron et al., 1994). Heavy-resistance training promotes hypertrophy in all three fibre types (I, IIa and IIb). The greatest growth is usually seen in Type IIa, followed by Type IIb, and the least growth in Type I fibres. Training with high velocity and at low loads does not lead to hypertrophic changes in fibres. Transitions appear to occur within the Type II subtypes, but there is no convincing evidence of transitions between Types I and II (Deschenes and Kraemer, 2002).

Muscle training is the main contributor to strength and power gains (Coyle et al., 1981; Behm and Sale, 1993). The influence of training is reflected both in neural adaptation and muscle fibre composition (Komi, 1973; Komi et al., 1978; Moritani and DeVries, 1979; Sale, 1988). Ross et al. (2001) also speculated in their review that the nerve conduction velocity might reflect the adaptation of nerve structure, with increased diameter of axon and myelination. This adaptation may decrease the refractory period of the nerve, which possibly allows increased impulse frequency and potentially increased muscle activation. A major part of the improvements in untrained subjects during the initial weeks in power-type strength training is probably due adaptations of the neural system, such as increased motor unit firing frequency, improved motor unit synchronization, increased motor unit excitability, and increase in efferent motor drive. Also, a reduction of the antagonist and improved co-activation of the synergist muscles may explain part of the changes (Häkkinen, 1994). In a study of Aagaard et al. (2002), the major part of the training induced improvements after 14 weeks of resistance training were explained by increases in efferent neural drive.

Power-type strength performance can be improved almost by means of any training method, provided that the training frequency and loading intensity exceed the normal activation of the muscle (Kaneko et al., 1983; Moritani et al., 1987, Häkkinen and Häkkinen, 1995; Kraemer, 1997; Häkkinen et al., 1998; Izquierdo et al., 1999; Jozsi et al., 1999; Häkkinen et al., 2000; Marx et al., 2001). In investigating the strength and muscle power output in upper and lower extremities in athletes engaged in various sports, Izquierdo et al. (2002) found that the maximal power output was produced at higher load condition in lower extremities (45–60% of 1 repetition maximum) than in upper extremities (30–45%). They suggested that the sports-related differences might be explained, in addition to training background, by differences in muscle cross-sectional area, fibre type distribution, and by the different muscle mechanisms of the upper and lower extremities. Kawamori and Haff discussed this finding in their review (2004) and suggested that another possible explanation for the differences may be the fact that during lower extremity exercises a larger part of body mass must be lifted up, compared with the upper extremity exercises. Several studies have shown enhancements in middle-aged and in older subjects in maximal and fast force production (Häkkinen and Häkkinen, 1995; Häkkinen et al., 1998; Izquierdo et al., 2001), in explosive jumping performances (Häkkinen et al., 1998; Häkkinen et al., 2000), and isotonic muscle power output in lower extremities (Jozsi et al., 1999).

Cavagna et al. (1971) were the first who showed that the elastic component of leg muscles provides the additional power that is required for sustaining the maximal velocity during sprint running. Furthermore, in studies of Mero et al. (1981) and Chelly and Denis (2001) multi-jump performances correlated highly with sprint running in young subjects. Consequently, Mero et al. (1981) proposed the drop jump test to be useful in predicting maximal running speed. Also, Young et al. (1995) found a high correlation between concentric squat jump performance and maximal running speed. Sprint running and initial acceleration represent a complex movement where the stretch-shortening cycle is dependent of the adaptation of the neuromuscular system and strength (Mero et al., 1981; Mero and Komi 1986, Cronin et al., 2000). Cronin et al. (2000) found that for stretch-shortening cycle actions of short duration, such in sprint acceleration, the greater maximal strength will lead to greater instantaneous power production. The same authors pointed out that in concentric actions which need high initial power production, such as vertical squat jump, the neuromuscular ability to produce the highest amount of power per time unit is more important than maximal strength. Stone et al. (2003) concluded that improved maximal strength was the primary component in improving the jumping power. Explosive exercises (Linnamo et al., 2000) and sprint training (Sleivert et al., 1995) also seem to facilitate the neuromuscular system.

Three times a week of resistance training is generally recommended for achieving enhancements in muscle strength and power in extremities (Pollock et al., 1998; Feigenbaum and Pollock, 1999). Previous reports indicate that, to achieve training effects, the minimum training frequency should be at least twice a week (Pate et al., 1995; DeMichele et al., 1997; Feigenbaum and Pollock, 1999; Kraemer et al., 2002). Previous studies also show that detraining leads to a decrease in strength and loss of training effect within a few weeks (Häkkinen and Komi, 1983; Narici et al., 1989; Häkkinen et al., 2000).

One of the major exercise methods has been the use of heavy loads to induce recruitment of high-threshold fast Type II motor units by the size principle (Sale, 1988). Another exercise method is to use light loads to maintain the specificity of the exercise velocity and to maximise the mechanical power output. Kaneko et al. (1983) reported that 30% of maximal load resulted in the greatest improvement in maximal mechanical power. There are several studies indicating the specificity of power training (Komi et al., 1982; Häkkinen and Komi, 1985; Scutter et al., 1995). Power-type strength training with lighter loads and higher shortening velocities has been shown to increase the force output at higher velocities, as well as the power development (Häkkinen and Komi, 1985). Muscular power increased significantly when high training volume and high-velocity exercises were used in training (Häkkinen and Häkkinen, 1995; Kraemer, 1997; Marx et al., 2001).

Previous reports support specificity of exercise type, i.e. the greatest training effects are achieved when the same type of training is used both in training and testing (Caiozzo et al., 1981; Kanehisa and Miyashita, 1983; Häkkinen and Komi, 1985; Ewing et al., 1990; Colliander and Tesch, 1990; 1992; Morrissey et al., 1995).

Experimental studies examining the effects of power-type strength training in middle-aged, sedentary men and women have usually compared the pre and post training effects of resistance training. Most of the intervention studies evaluating the effects of power-type strength and resistance training are conducted with younger and physically active subjects. Moreover, randomised, controlled studies in this field are sparse. Especially few are training interventions evaluating both the training effects and the feasibility aspects, including injuries, adherence and motivation. A summary of previous studies with power-type strength training programmes in the training protocol is presented in Table 1.

2.1.3. Effects of power-type strength training on trunk muscles

Table 1. Summary of power-type strength training intervention studies in healthy subjects.

Reference	Age (years)	N	Sex	Exercise type	Training period	Muscle	Training effect (%)	Measured by
Häkkinen and Komi, 1985	27 ± 3, used to training	10	M	Explosive strength training, jump exercises with and without loads	24 wks (3 x/w)	Leg	21% (max strength increased by 7%)	Squat jump height
Baker et al., 1994	20 ± 3 athletes	22	M	Strength training, squat lifts	12 wks (3 x/w)	Leg	8%	Vertical squat jump
Häkkinen et al., 1998	39–42 and 67–72	42	F/M	Heavy RT combined with explosive exercises 50%–80% of 1RM	6 mths (2 x/w)	Leg	11%–14% in middle-aged and 18%–24% in older men and women	Vertical Squat jumps on a force plattform
Izquierdo et al., 2001	46 ± 2 and 64 ± 2	22	M	Heavy RT 50–70% of RM and 8 weeks 20% of exercises where explosive type with 30–50% of RM	16 wks (2 x/w)	Knee	46% and 37% measured with a relative load of 60% (less with other loads)	Measured by relative loads of 0, 15, 30, 45, 60 and 70% of 1RM with max knee extension in half-squat
Newton et al., 2002	30 ± 5 (n = 8) 61 ± 4 (n = 10)	18	M	Mixed RT: hypertrophy, strength and power	10 wks (3 x/w)	Leg and trunk	33–36% (similar improvements in both age groups)	Squat jump measured by 30% 1RM load
Jones et al., 2001	20 ± 2, athletes	15	M	RT 40%–60% 1RM, squat lifts	10 wks (4 x/w)	Leg	3%–12%	Countermovement jump (6%–12%), depth jump (9%), 1RM squat (6%–12%), angle jump (3%)
Wilson et al., 1993*	22 ± 7, athletes	26	M	Plyometric training group Power training (30% of RM) group	10 wks (2 x/w)	Leg	0% in 30 m sprint, 6% in squat jump 1.5% in 30 m sprint, 14% in squat jump	30 m sprint test Vertical squat jump
Delecluse et al., 1995	18–22, students	21	M	Unloaded plyometric exercises with maximal effort	9 wks (2 x/ w)	Leg	7%	10 metres sprint acceleration
McBride et al., 2002	24 ± 2	9	M	Light load (30% 1RM) jump squat exercises	8 wks (2 x/w)	Leg	Jump height 17%, peak velocity 9%, agility and 20 m sprint:1–2%	Agility test, 20 metre sprint and squat jump tests
Blazevich and Jenkins, 2002	19 ± 1, sprinters	9	M	High-velocity RT and running (group A) Low-velocity RT and running (group B)	7 wks (2 x/w)	Leg	2% in 20 m sprint, 12% in squat jump (group A) (speed of RT did not effect the sprint performance)	20 metre sprint with flying start squat jump
Kyröläinen et al., 1989	25 ± 5	9	F	Jump and strength exercises (no load)	4 mths (3 x/w)	Knee	21%	Angular knee velocity with a load of 10 kg
Jozsi et al., 1999	26 ± 1 and 60 ± 1	34	F/M	RT with pneumatic machines (isotonically), intensity of 40, 60 and 80% of 1RM	12 wks (2 x/w)	Knee extensors	11%–14% in young subjects and 17%–21% in older, measured with 40% of 1RM	Pneumatic resistance equipment
Aagaard et al., 1994	23 ± 1, football players	6	M	Loaded kicking movements	12 wks (3 x/w)	Knee extensors	7–13% (improvements were related to angular velocities during training)	Isokinetic dynamometer
Earles et al., 2001*	77 ± 5	18	M/F	Rapid movements in knee extensors	12 wks (3 x/wk)	Knee extensors	22% power improvement	Knee dynamometer
Kemmler et al., 2002	56 ± 3	59	F	12 weeks of endurance, from 5th month to 10 th month jumping exercises	14 mths, (2 x/w + 2 x/w)		13% in leg press from 5 months to 10 months (jumping exercise period)	Horizontal leg press in 5 months and 10 months 50% 1RM
Häkkinen et al., 2001	40 ± 12 and 69 ± 3	42	F/M	Total body strength training 50–80% of RM (25% explosive exercises with 50–60% RM)	6 mths (2 x/ w)	Knee extensors	Explosive strength (improved by) 21%–2%	Knee dynamometer
Aagaard et al., 2002	23 ± 4	15	M	Progressive RT, 4–12 RM low to heavy resistance	14 wks	Knee extensors	Knee extension strength (increased by) 15%. Rate of force development (increased by) 15%	Knee dynamometer and EMG
Kraemer et al., 2001*	33 ± 8	9	F	RT (10 repetition maximum) combined with step-aerobic	12 wks (3 x/w)	Knee extensors	increase in 1RM squat by 26% increase in squat jump power by 13%	Squat jump

RT = Resistance Training, * = Randomized Controlled Trial

Despite the large number of different exercise protocols for trunk muscles, scientific research investigating the specific effects of power-type strength training on trunk muscle velocity in healthy subjects is lacking. However, several studies concerning the exercise effects in low back patients have shown that improved muscular fitness, trunk muscle strength and power or spinal flexibility may prevent future low back pain and spinal disorders (Biering-Sorensen, 1983; Suzuki and Endo, 1983; Mayer et al., 1985; Lahad et al., 1994; Harreby et al., 1997; Abenheim et al., 2000). Trunk muscles should be trained by various types of exercises (aerobic, strength and power training) in order to provide many-sided and sufficient loading for lumbar muscles. In a recent study of Pedersen et al. (2004) the authors showed that exercises which focused on reactions to various expected and unexpected sudden trunk loadings together with coordination exercises can improve the response to sudden trunk loading in healthy subjects, without an increase in pre-activation and associated trunk muscle stiffness. Lumbar exercises are recommended in chronic and even in sub-acute low back pain, but not in acute phase (Abenheim et al., 2000). According to previous reports, it appears that a training frequency of 1–2 times a week elicits optimal gains in strength and power in trunk muscles (Graves et al., 1990; Tucci et al., 1992; DeMichele et al., 1997; Pollock et al., 1998). Previous studies (Graves et al., 1990; Pollock et al., 1989; Tucci et al., 1992) have investigated the effects of training frequency on increased strength of lumbar extension muscles, which, unlike the other muscle groups, have a large potential for strength gains. Improved lumbar extension strength can be maintained up to 12 weeks with a very low training frequency (1 session per 2 or 4 weeks), when the volume, type and intensity of training are constant (Tucci et al., 1992).

2.1.4. Feasibility of power-type strength training in middle-aged subjects

Ageing leads to a loss in muscle mass, a decrease of strength and a decline of contractile velocity (Aniansson et al., 1981; Frontera et al., 1991). The main reason for age-related decrease in strength is muscle fibre atrophy (Lexell et al., 1988) and the decreased contractile velocity may be related to a reduction of the relative proportion of fast Type II muscle fibres (Lexell et al., 1988; Proctor et al., 1995). This process accelerates in the beginning of the sixth decade both in men and women (Lexell, 1988; Häkkinen, 1994). In a study among men and women aged between 20 and 84 years, Akima et al. (2001) estimated that the leg extension and flexion strength declined by 8% on decade in women and by 12% in men. Metter et al. (1997) reported that the decrease of muscle power is 10% faster than decrease of strength in ageing men. Savinainen et al. (2004) investigated the changes in physical capacity (hand-grip-, trunk flexion and extension strength and aerobic capacity) during a 16 year follow-up period and found a greater decrease of physical capacity in men (ranging from 11.6% to 33.7%) than in women (ranging from 3.3% to 26.7%).

Muscle strength and the ability of the leg muscles to produce force rapidly are of importance, especially with increasing age, in connection with daily activities, and even in prevention of falling (Bassey et al., 1992; Skelton et al., 2002). Samson et al. (2000) found that the decline of leg muscle strength and functional mobility accelerated in women from the age of 55 years onwards; in men the decline was more gradual. In healthy urban population of 35-, 45- and 55-year-old men and women, the vertical jumping height was 25% greater in 35-year-old men than in 55-year-old men, but the 35-year-old men were only 15% stronger in trunk muscles than 55-year-old men (Viljanen et al., 1991; Era et al., 1992). The average vertical jumping height was at least as good in physically active subjects as in those who were 10 years younger but physically inactive (Kujala et al., 1994). In the same study, the authors observed that mixed training with varied types of exercises for the neuromuscular system enhanced the jumping height most. Korhonen et al. (2003) showed in their recent study that the age-related deterioration in sprint running in former sprint athletes was associated with reduced stride length and increased ground contact time.

For the purpose of maintaining functional capacity, strength and power-type strength training are recommended for middle-aged and elderly people (Häkkinen et al., 1998; Izquierdo et al., 1999). In strength training the minimum of two sessions a week is recommended for the adult healthy population (ACSM, 1998; Feigenbaum and Pollock, 1999; Kraemer et al., 2002). Probably the same frequency is also needed for maintaining and enhancing the power-type strength characteristics.

Previous studies on supervised resistance training programmes (Tsutsumi et al., 1997), controlled circuit weight training programmes (Norvell and Belles, 1993) and anaerobic training programmes (Norris et al., 1990) indicate that these training modes are beneficial both for physical and psychological health. The perception of physical ability and perceived fitness have improved in physical training interventions in adults, independently of the type of activity (Caruso and Gill, 1992; Bravo et al., 1996). Studies evaluating the effects of power-type strength training programmes in middle-aged and older subjects are sparse (see Table 1).

For being effective in enhancing explosive muscle performance, the training programmes designed for middle-aged and older subjects should take into consideration, in addition to age and gender, the existing musculoskeletal symptoms, previous injuries, and exercise history. A population survey (Uitenbroek, 1996) showed that exercise-related injuries constitute a high proportion of all injuries, particularly in men. The amount of previous injuries and exposure time may also increase the risk for injuries (Van Mechelen et al., 1992; 1996). Poor physical condition increases the risk of training induced injuries (Lysens et al., 1991) and highly intensive fitness programmes may even have non-beneficial effects on physical health among less fit subjects in the form of injuries, increased muscle pain, muscle soreness and other training-related inconveniences (Egwu, 1996). When an injury occurs, athletic and well-trained subjects suffer more of post-injury mood disturbances (caused by the loss of active training time) than less trained people (Little, 1969; Smith, 1996).

Exercise programmes should to be safe enough for the exercisers to avoid injuries and musculoskeletal consequences. This is especially important in programmes designed for middle-aged, sedentary men and women. Injuries and musculoskeletal symptoms also influence the exercise motivation. Approximately 30% of adult population in Finland (Helakorpi et al., 1998) and the United States (Caspersen and Merrit, 1995) are sedentary. Physical activity generally declines with age, with a temporary increase in activity at the time of retirement (Bouchard et al., 1994). The decline is greatest when the activity is vigorous and unorganised, and the decrease is greatest in men. Also, men are engaged more often in vigorous physical activities than women (Caspersen et al., 2000; Sallis, 2000).

In Finland, physical activity declines in early adulthood and begins to increase again at the age of 45–54 years (Helakorpi et al., 1998). Physical activity can be promoted by various kinds of interventions. In group-based exercise programmes the adherence has been highest in interventions of short duration (Bij et al., 2002), but the effects are usually temporary (Dishman and Buckworth, 1996). In an aerobic exercise programme, the dropout rate was approximately 50% within six months (Robison and Rogers, 1994). Adherence to physical activity is a complex interaction of personal, behavioural and environmental conditions, including perceived health and fitness, marital status, smoking, obesity, lack of time, previous exercise behaviour, socio-economic status and neighbourhood (Grzywacz and Marks, 2001; Trost et al., 2002). The adherence is lower in high-intensity training, but high training frequency is necessarily not associated with low adherence (Perri et al., 2002). Future adherent behaviour in supervised training programmes is positively influenced by previous physical activity, perceived health and fitness, the spouse's support, agreements and training facilities (Dishman et al., 1985).

3. THEORETICAL FRAMEWORK OF THE STUDY

Muscle strength and power-type strength decrease with increasing age and also with inactivity. The decrease accelerates at the onset of the sixth decade both in men and women. The loss of muscle strength is observed in all muscles in the body, but the loss may be earlier and greater in the proximal part of leg muscles compared with arm and trunk muscles, probably caused by a lower use of leg muscles compared with the arms and trunk. Maintaining strength and power-type strength capacities at increasing age is relevant for a number of reasons, including prevention of falls, maintenance of joint mobility, and performance of daily activities.

Training intervention studies, and especially randomised studies, investigating the effects of power-type strength training on leg and trunk muscles, and further evaluating the feasibility of the programme in question are sparse. The results of exercise interventions where explosive exercises have been used in groups of sedentary, as well as athletic middle-aged and older people are promising. However, most of the studies have been conducted with a small number of participants, and the exercise mode has in most studies been strength or resistance training combined with explosive exercises, rather than explosive exercises alone (Table 1).

As far as we know, there are very few studies on purely power-type strength training programmes in middle-aged and older men and women. The feasibility of this type of training programme, including such aspects as training motivation, training adherence, training induced injuries, musculoskeletal symptoms, and the impact of perceived health and fitness, should also be investigated by using reliable and validated measurement methods.

4. AIMS OF THE STUDY AND STUDY DESIGN

4.1. Aims of the study

The general purpose of this study was to investigate the effects of a power-type strength training programme on leg and trunk muscles, and to examine the training responses in men and women with high, moderate and low training activity. Additionally, the feasibility of the power-type strength training programme for middle-aged, sedentary men and women was evaluated. The following qualities were set for the programme design: the programme should be simple and practical, and it should encourage and motivate middle-aged men and women to increase their overall physical activity by getting accustomed to and adopting power-type strength training.

The individual studies were performed to specifically answer the following questions:

1. Does the use of light external loading (totalling 2.2 kg) in lower extremities increase the efficiency in power-type strength training exercises? (Study 1)
2. Which training frequency is needed for improved angular velocity of the trunk muscles in power-type strength training in middle-aged men and women? (Study 2 and 3)
3. What is the influence of power-type strength training on perceived health, musculoskeletal symptoms and injuries in middle-aged men and women? (Study 4)
4. What is the adherence rate in men and women, and what are the reasons for dropping out from the power-type strength training programme? (Study 5)

4.2. Study design

Two hundred and fifty-two (252) subjects volunteered to the study. A total of 171 participants completed the training programme, and 55 subjects dropped out during the training programme (Study 5). The control group consisted of 26 non-exercising volunteers (Figure 1).

For evaluating the impact of light loads attached to the lower extremities, the exercisers were divided into two subgroups, one with light loads and one without any loads. The results of those exercisers whose training attendance was at least twice a week (high training group) were included in the analysis (Study 1).

For evaluating the training frequency vs. training response, the participants were classified into three training frequency groups according to their attendance at the exercises, and to a non-exercising control group. The subjects with training attendance rate $\geq$ 67% (2–3 times a week) were classified as female and male high training groups; the subjects with training attendance rate between 33% and 67% (1–2 times a week) were classified as female and male moderate training groups, and the subjects with attendance rate < 33% (less than once a week) or with at least six weeks of detraining period at the end of the intervention were classified as female and male low training groups. The numbers of subjects participating in different physiological measurements are presented by the training attendance groups in Table 2.

For analysing the effects of training frequency on trunk muscles, the participants were classified into two training frequency groups (Study 3). The design of the study is presented in Figure 1.

The physical performance measurements were performed and questionnaires were answered one week before the training programme started, and same procedure was carried out one week after the training programme ended. The study was completed within two years: a new controlled and supervised exercise class started once 10–20 subjects had been measured, and the group continued training together for the whole training period of 22 weeks. The training programme included three progressive periods. The orientation period consisted of basic strength and conditioning exercises (6 weeks). The second period consisted of training for explosive strength and velocity (10 weeks), and the last period consisted of velocity training (6 weeks).

5. METHODS

5.1. Subjects

To be eligible for the intervention, the participants should be middle-aged, healthy and sedentary. All participants were examined by a physician to be qualified to participate. Medical screening included cardiovascular, neurological and musculoskeletal examinations. The physical activity level was assessed by interviewing the subjects (those who trained sports regularly, at least three times a week, or had been training in the past five years were excluded from the study).

Participants (n = 252) were recruited among the staffs of the local university and polytechnic institutes, secondary schools and private companies, or among the participants of retraining courses and

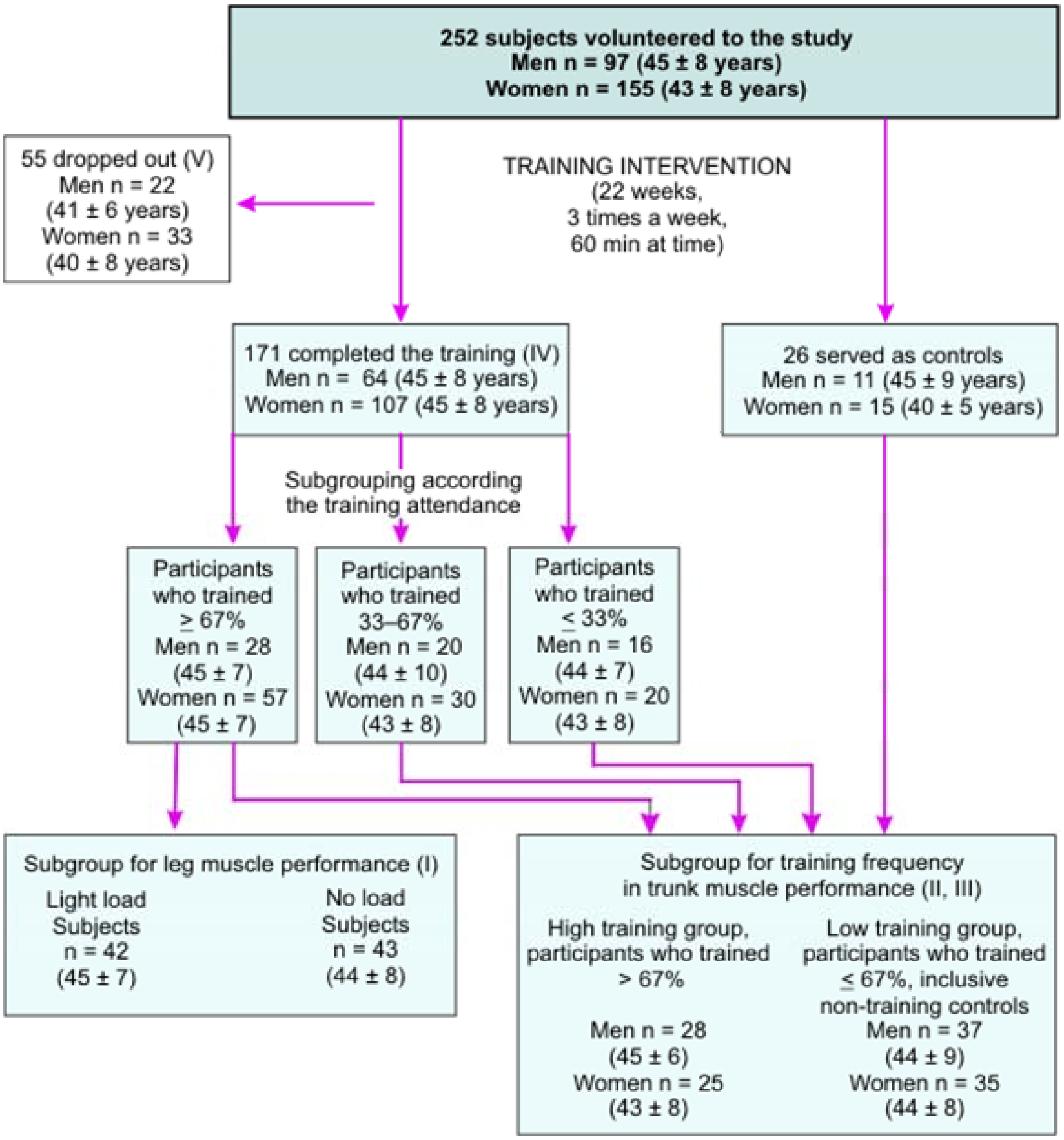

Figure 1. The flow chart of the study design and major subgroups in the data analysis.

the members of a local association of the unemployed. The recruiting information was the same for all. Brochures about the training intervention were attached on billboards providing the following information: "The aim of this study is to develop in practice power-type strength exercises that are simple to perform and feasible for anybody. Exercise sessions are supervised, and various physiological measurements are carried out before and after the intervention". The groups were also reached by e-mail and by visiting people at their jobs, course centres and institutes with the purpose of recruiting volunteers to the intervention. The subjects in the training group (men n = 86, women n = 140) and in the non-exercising control group (men n = 11, women n = 15) were healthy and middle-aged, and most of the subjects were sedentary (Tables 3 and 4). All subjects were informed of the purpose of the study before they gave their written consent to participate in the study. The Ethical Committee of the Research and Development Centre of the Social Insurance Institution approved the study protocol.

5.2. Measurements

After the medical examination the following measurements were carried out on four different days: Vertical squat jump, Trunk muscle performances and all inquiries (Day 1); Maximal anaerobic cycling power (Day 2); Maximal oxygen uptake (Day 3); and Standing long jump and 20 metre running time (Day 4).

Table 2. The number of participants in various measurements and respondents to questionnaires in different training activity groups.

Study	Measurement Training activity group	Male exercise group (n)	Female exercise group (n)	Male control group(n)	Female control group (n)
	Vertical squat jump (cm)	*61*	*104*	*10*	*12*
1, 4	High training group	28	57		
	Moderate training group	17	30		
	Low training group	16	17		
	Standing long jump (cm)	*49*	*102*	*6*	*7*
4	High training group	24	56		
	Moderate training group	16	29		
	Low training group	9	17		
	20 metre running time (s)	*61*	*104*	*10*	*12*
1	High training group	28	57		
	Moderate training group	17	30		
	Low training group	16	17		
	Maximal anaerobic cycling power (W) and Maximal oxygen uptake ($kg \cdot ml^{-1} \cdot kg^{-1}$)	*40*	*38*	*6*	*10*
1	High training group	20	19		
	Moderate training group	9	12		
	Low training group	11	7		
	Trunk flexion/extension (Nm and $Deg \cdot s^{-1}$)	*57*	*50*	*8*	*10*
2, 3	High training group	28	25		
	Moderate training group	14	17		
	Low training group	15	8		
	Questionnaires (Perceived health, fitness, physical activity, musculoskeletal symptoms, socio-economic status)	*64*	*107*	*10*	*8*
4, 5	High training group	28	57		
	Moderate training group	20	30		
	Low training group	16	20		

5.2.1. Vertical Squat Jump (Study 1)

Vertical Squat Jump (VSJ) (cm) was used to measure the explosive force of leg muscles before and after the intervention. Participants had three attempts in vertical squat jump, with 1–3 minutes' rest between the attempts. The best value (cm) of the three trials was included in the statistical analysis. VSJ was measured by using a contact mat (Newtest powertimer®, Finland). The recorded flight time (s) was transformed to centimetres (cm) (Bosco et al., 1982; 1983). Participants were barefoot, with knees flexed at 100 degrees, and they held a wooden stick behind the neck to standardise the position of arms and upper body.

5.2.2. 20 metre Running Time (Study 1)

20 metre Running time (20mRT) (s) was measured with a flying start, and the first 5 metres were omitted from the calculation of the running time. Participants had three attempts in running speed, with 1–3 minutes' rest between the attempts. The best result was used in the statistical analysis.

5.2.3. Standing Long Jump (Study 4)

Standing Long Jump (SLJ) (cm) was used to measure the explosive force of leg muscles in horizontal direction. Subjects jumped from a standing position, swinging of arms and leg counter-movements were permitted. Participants had three attempts. The best result was used in the statistical analysis.

5.2.4. Maximal Anaerobic Cycling Power (Study 1)

The Maximal Anaerobic Cycling Power (MACP) (W) test is a cycle ergometer modification of an anaerobic power test on a treadmill (Rusko et al., 1993; Rusko and Nummela, 1996). MACP consisted of 3–8 cycling bouts lasting 20 s each with a 100 s recovery between the bouts. The pedalling frequency

Table 3. The profile of male participants in the different training attendance groups and in the dropout group, before the training programme started. Percentage (%) of different variables.

	Highly trained (n = 28)	**Moderately trained (n = 20)**	**Low trained (n = 16)**	**Male dropouts (n = 22)**
Age (years ± SD)	45 ± 7	44 ± 10	44 ± 7	41 ± 6
Body mass index ($kg \cdot m^{-2}$)	27 ± 3	27 ± 3	27 ± 3	28 ± 4
Smokers (%)	18	25	38	27
Previously physically active (%)	82	80	88	73
At present physically active (%)	71	75	75	50
Plenty/some physical leisure activity at present (%)	86	90	81	54
Employed (%)	89	90	88 **	59
Good perceived health (%)	72	75	75	68
Good perceived fitness (%)	36	50	44	9
Neck symptoms (%)	29	20	50	27
Shoulder symptoms (%)	39	25	56	23
Low back symptoms (%)	46	35	69	27
Knee symptoms (%)	32	25	13	14
Ankle symptoms (%)	11	15	25	27

** denotes $p < 0.01$ between the groups.

was constant, 90 rpm for men < 40 yrs and 86 rpm for women and men ≥ 40 yrs. The work rate of the initial bout was determined by the subject's body weight and estimated physical fitness, supposing that sedentary subjects were within the range of average maximal oxygen uptake of population (or less). The load was increased by 30–60 W in general, depending on the subject's age, gender and physical fitness. The work rate was increased after every recovery in equal increments throughout the test. Cycling power, pedalling moment and pedalling frequency were recorded and saved on a computer. A cycling bout was accepted if the pedalling rate was not decreased by 5% or more from the target speed. The subject continued the test until he or she could not cycle at the target rate. The test ended at the moment when the pedalling rate was decreased by 5%. To be acceptable, the final bout was not to be shorter than 12 s. The maximum of the moving average over the 5 s period of cycling power was applied for describing the maximal anaerobic cycling power of the subject. The cycle ergometer used in the test was RE 820 (Rodby Elektroniks AB, Södertälje, Sweden), which was modified to give power output of 1000 W with high pedalling rate.

5.2.5. Maximal oxygen uptake (Study 1)

Maximal oxygen uptake (VO_2max) ($ml \cdot kg^{-1} \cdot min^{-1}$) was measured to evaluate the subject's endurance capacity. A 2-min incremental exercise test on the electromagnetically controlled cycle ergometer (Rodby Ergometer RE 820®, Södertälje, Sweden) until volitional exhaustion or fatigue of the lower limbs was employed for measuring the VO_2max. The subjects pedalled at a constant frequency of 60 rpm. The test was preceded by a 4-min warm-up at 30 W to become familiar with the pedalling frequency, mouthpiece and nose clips. Thereafter, work rate was increased every 2nd min, with equal increments throughout the test. The increments were individually determined (10–25 W) on the basis of the subject's physical fitness to reach the maximum work rate in approximately 12–15 min. The test continued until the subject was unable to maintain pedalling frequency above 45 rpm. Respiratory gas exchange variables were determined continuously with a breath-by-breath method suing the SensorMedics Vmax 229® equipment. The VO_2 values were averaged over the breath-by-breath values of the 30-second intervals. VO_2max was recorded as the highest averaged value at the maximum work rate. The corresponding heart rate and work rate were recorded and represented their maximums. Subjects rated their perceived exertion

Table 4. The profile of female participants in the different training attendance groups and in the dropout group, before the training programme started. Percentage (%) of different variables.

	Highly trained (n = 57)	**Moderately trained (n = 30)**	**Low trained (n = 20)**	**Female dropouts (n = 33)**
Age (years ± SD)	45 ± 7	43 ± 8	43 ± 8	40 ± 8
Body mass index ($kg \cdot m^{-2}$)	24 ± 4	25 ± 4	25 ± 3	24 ± 4
Smokers (%)	9	20	10 *	52
Previously physically active (%)	72	73	80	70
At present physically active (%)	44	57	65	33
Plenty/some physical leisure activity at present (%)	68	83	70	58
Employed (%)	93	80	80 ***	51
Good perceived health (%)	75	73	90	76
Good perceived fitness (%)	26	40	45	27
Neck symptoms (%)	47	40	40	31
Shoulder symptoms (%)	59	63	45	55
Low back symptoms (%)	42	57	25	39
Knee symptoms (%)	23	20	20	21
Ankle symptoms (%)	16	17	15	12

** and *** denote $p < 0.007$ and 0.001, respectively, between the groups.

using the Borg scale 6–20 (Borg, 1982) and the amount of fatigue in their lower limbs on scale 1–5 every 4 minutes at the beginning and every 2 minutes later on during the test and at the end of the test in order to evaluate subjective feelings along the whole exercise test and the character of subjective maximum.

5.2.6. Isometric and dynamic trunk Flexion and Extension torques and angular velocities (Study 2, 3)

Isometric trunk flexion (IsomFL) (Nm) and extension (IsomEX) (Nm) torques, and the trunk flexion (FLTorq) (Nm) and extension (EXTorq) (Nm) torques during dynamic actions, and the angular velocities during flexion (FL_{vel}) ($deg \cdot s^{-1}$) and extension (EX_{vel}) ($deg \cdot s^{-1}$) were measured by using a triaxial, isoresistive lumbar dynamometer (Isostation B-200®, Isotechnologies, Hillsborough, NC, USA). The system allows simultaneous measurement of the velocity, angular position and torque of the three spatial axes of the body spine.

5.2.7. Questionnaires (Study 1, 4, 5)

Questionnaires were used to inquire about the physical activity, smoking, employment status, motivation for exercising, and perceived health, fitness and musculoskeletal disorders. The participants filled in a questionnaire asking yes or no questions about the present and previous physical activity (excluding school-time sports activities), smoking (yes or no) and employment (yes or no).

Perceived health and fitness were assessed by using a five-point Likert scale (poor, fairly poor, average, fairly good, good) used by, among others, Moum (1992) and Wolinsky and Johnson (1992). This method has shown to be reliable and consistent with the assessed medical health and its functional consequences (Lundberg and Manderbacka, 1996; Manderbacka, 1998).

For the assessment of musculoskeletal disorders, the standardised Nordic musculoskeletal questionnaire (Kuorinka et al., 1987) was used. The subjects were inquired about the presence of neck, shoulder, low back, hip, knee and ankle symptoms during the preceding six months. Further, the participants were in advance instructed to report the instructor about any injuries occurring during the training programme, and to describe the injuries in detail. In order to minimise the number of missing reports, the participants were given a questionnaire form for reporting the injuries. They were also asked to evaluate whether the injury was acute or a result of overuse.

5.3. Training

The power-type strength training programme was based on the general training principle with the exercises performed with low loads, but with high movement velocities. The aim was to activate the muscles subject to training by various exercises to a high or maximal degree, with a short activation time. This type of training leads to improvements primarily in the earlier force portion of the force-time curve or the higher velocity portions of the force-velocity curve (Häkkinen, 1994).

Training sessions were supervised and controlled by a qualified instructor. The duration of the training programme was 22 weeks, including 52 training sessions, which lasted 60 minutes each. The targeted exercise frequency was three times a week. The training programme (described in detail in original Studies 1, 3 and 5) was progressive, with an emphasis on power-type strength training. The programme included the following three periods: the first period of 6 weeks consisted of basic physical exercises, the second period of 10 weeks consisted of power-type strength training and the third period of 6 weeks consisted of power-type strength and velocity training. The purpose of the first period was to familiarise the exercisers with physical training and to enhance muscle strength and co-ordination skills. The second period consisted of power-type strength training with submaximal and maximal intensity. The third period consisted of power-type strength and high-velocity training with maximal intensity. During the first exercise week the intensity of training was determined individually for each participant on the basis of maximal Number of Repetitions subjects performed during 60 s (NR). The maximal Number of Repetitions during 60 seconds was calculated for various types of exercises. The exercises focused on leg (approximately 60%) and trunk muscles (approximately 40%). Training was carried out in male and female exercise classes of 10–20 subjects. After the first 6 week period exercisers were divided into Light Load (LL) or into No Load (NOL) groups. Exercisers in the LL group had 1.1 kg weights in each ankle during all exercises. Each exercise class consisted of either LL or NOL exercisers.

5.4. Statistical analyses

The General Linear Models Procedure (GLM) of the Statistical Analysis System (SAS/STAT, 1989) was applied to compare the changes between the groups and to evaluate possible interaction between group and gender, and for multiple comparisons between the groups. Mean changes and lower and upper 0.95 confidence limits of the outcome variables in three different training activity groups and the control group were calculated by gender. Means, standard deviations and correlation coefficients were calculated by standardised methods.

For the comparison of the changes in the Light Load (LL) and No Load (NOL) groups (Study 1), the individual data for VSJ, 20mRT, MACP and VO_2max at the baseline and after the intervention were presented in scatter-plots. The chi-square test was applied to examine the distribution of the type of previous exercise activity (four categories: endurance type, power-type, no exercise history, and other leisure activity than endurance or power-type), and the pre-training shoulder-neck, low back, hip, knee and ankle symptoms. The t-tests were used to analyse the differences between the mean values of the baseline measures and the changes in the LL and NOL groups.

The Linear Structural Relationships (LISREL) model was used to analyse the flexion and extension movement velocities and the reliability of the measurement (Study 2). The LISREL model facilitated understanding the nature of the measured flexion and extension movement, movement velocity and range.

For the analysis of the trunk muscle performances (Study 3), one-way analysis of variance (Procedure GLM of the Statistical Analysis System) was applied to compare the changes of the outcome measures between two (high vs. low training) groups by gender. The chi-square tests were applied to investigate the differences in low back symptoms, perceived health, physical activity, and smoking between the groups. Mean changes and lower and upper 0.95 confidence limits of the outcome variables in three different training activity groups and the control group were calculated by gender. Means, standard deviations and correlation coefficients were calculated by standardised methods.

The chi-square test and the GLM procedure analysis were applied to examine the distribution of the musculoskeletal symptoms, smoking, employment, perceived health, perceived fitness, overall physical activity (present and previous) and smoking between the groups. To investigate whether there were any changes in perceived health, in perceived fitness, or in the incidence of knee and low back symptoms during the training programme, the marginal probabilities of two-dimensional contingency tables were used and analysed by gender using Proc Catmod SAS/STAT (Study 4).

The chi-square tests and the GLM Procedure analysis were applied to investigate the associations with training activity and employment, smoking and age (Study 5).

6. RESULTS

6.1. Study subjects and training effects on leg muscle performances in exercisers and non-training controls

One hundred and seventy-one (171) participants (64 men and 107 women) completed the training programme. The control group consisted of 26 non-exercising volunteers (11 men and 15 women). Of the initial group, 55 dropped out (22 men and 33 women) during the training programme. The overall dropout rate in this study was 24%. The overall training activity was 63% for those (n = 171) who completed the programme. The baseline characteristics of the subjects are presented in Tables 3 and 4, including age, body mass index, perceived health and fitness, jump performance, and knee and low back symptoms. At the baseline, the exercisers (n = 171) did not differ from the non-exercising controls (n = 18) or dropouts (n = 55).

In performances requiring power-type strength the most visible training effects were observed in vertical squat jump with 18% improvement in exercisers (15% in men and 20% in women), while in controls the increase was 1% (no change in men and 2% increase in women). Trunk flexion velocity improved in exercisers by 14% (13% in men and 15% in women), whereas in controls the increase was 3% (5% in men and 1% in women). The improvement in extension velocity was 16% (15% in men and 17% in women) in exercisers, while the increase in controls was 5% (7% in men and 3% in women). The exercisers improved their results in standing long jump by 4% (1% decrease in controls), 20 metre running time by 5% (no change in controls) and maximal anaerobic cycling power by 6% (1% increase in controls). In maximal oxygen uptake, which was measured for individual endurance capacity, a 4% improvement was observed in exercisers (2% decrease in controls). The changes in the non-training control group were not significant in any of the measurements. The pre- and post-intervention values and the percentage changes of the vertical squat jump (cm), standing long jump (cm), 20 metre running time (s) and maximal anaerobic cycling power (W) for the different training activity groups in men and women are presented in Tables 5 and 6.

There were significant differences in changes between the groups in vertical squat jump ($F = 19.33$, $df = 3$, $p = 0.0001$), in standing long jump ($F = 4.20$, $df = 3$, $p = 0.007$), in maximal oxygen uptake ($F = 3.10$, $df = 3$, $p = 0.03$), in 20 metre running time ($F = 11.35$, $df = 3$, $p = 0.0001$), and in maximal anaerobic cycling power($F = 4.83$, $df = 3$, $p = 0.0003$). In vertical squat jump the changes were higher in all of the training groups compared with the controls ($p < 0.05$). In 20 metre running time, the

Table 5. The pre- (Pre-interv) and post-intervention (Post-interv) values and the percentage change of Vertical Squat Jump (VSJ), 20 metre Running Time (20mRT), Standing Long Jump (SLJ), Maximal Anaerobic Cycling Power (MACP) and Maximal Oxygen uptake (VO_2max, $ml \cdot kg^{-1} \cdot min^{-1}$) in male training activity and control groups. Data are means (±SD).

		Highly trained men	Moderately trained men	Low trained men	Male controls
VSJ (cm)	Pre-interv	28 (4)	26 (4)	28 (5)	25 (5)
	Post-interv	32 (4)	30 (5)	32 (7)	25 (5)
	Change (%)	14 ***	16 ***	15 ***	0
20mRT (s)	Pre-interv	2.81 (.21)	2.95 (.25)	2.93 (.54)	3.00 (.25)
	Post-interv	2.71 (.18)	2.81 (.25)	2.89 (.43)	3.01 (.27)
	Change (%)	3 **	5 ***	1	0
MACP (W)	Pre-interv	555 (82)	542 (124)	542 (101)	499 (80)
	Post-interv	592 (84)	586 (136)	551 (93)	517 (78)
	Change (%)	7 ***	8 ***	2	4
SLJ (cm)	Pre-interv	233 (19)	225 (23)	229 (26)	216 (30)
	Post-interv	240 (20)	228 (24)	235 (29)	216 (30)
	Change (%)	3 ***	2	3	0
VO_2max	Pre-interv	40 (7)	39 (6)	40 (10)	35 (3)
	Post-interv	42 (7)	39 (7)	41 (9)	33 (3)
	Change (%)	4 *	1	1	-5 *

*, ** and *** denote $p < 0.05$, 0.01 and 0.001, respectively, between the measurements.

Table 6. The pre- (Pre-interv) and post-intervention (Post-interv)and the percentage change of Vertical Squat Jump (VSJ), 20 metre Running Time (20mRT), Standing Long Jump (SLJ), Maximal Anaerobic Cycling Power(MACP) and Maximal Oxygen uptake (VO_2max, $ml·kg^{-1}·min^{-1}$) in female training activity and control groups. Data are means (±SD).

		Highly trained women	Moderately trained women	Low trained women	Female controls
VSJ (cm)	Pre-interv	18 (4)	19 (4)	19 (4)	23 (7)
	Post-interv	22 (4)	22 (4)	22 (4)	23 (8)
	Change (%)	22 ***	19 ***	14 ***	2
20mRT (s)	Pre-interv	3.65 (.39)	3.73 (.42)	3.65 (.49)	3.22 (.61)
	Post-interv	3.40 (.34)	3.48 (.34)	3.54 (.48)	3.24 (.63)
	Change (%)	7 ***	7 ***	1	-1
MACP (W)	Pre-interv	350 (48)	333 (45)	313 (48)	389 (76)
	Post-interv	376 (48)	346 (50)	321 (39)	389 (85)
	Change (%)	8 ***	4 *	3	0
SLJ (cm)	Pre-interv	165 (20)	164 (19)	167 (27)	186 (31)
	Post-interv	173 (20)	172 (18)	172 (23)	185 (37)
	Change (%)	6 ***	5 ***	4 *	-1
VO_2max	Pre-interv	32 (6)	27 (6)	28 (5)	33 (10)
	Post-interv	34 (7)	29 (6)	29 (4)	33 (10)
	Change (%)	6 *	6	3	0

* and *** denote $p < 0.05$ and 0.001, respectively, between measurements.

changes were greater in the high and moderate training groups compared with the controls ($p < 0.05$). In standing long jump, in maximal anaerobic cycling power and in maximal oxygen uptake the changes were greater in the high training group compared with the controls ($p < 0.05$). In maximal anaerobic cycling power the changes were greater in the high training group compared with the low training group ($p < 0.05$).

Mean changes and 0.95 confidence limits in vertical squat jump (Figure 2a), 20 metre running time (Figure 2b), standing long jump (Figure 2c), maximal anaerobic cycling power (Figure 2d), and maximal oxygen uptake (Figure 2e) are shown for the three training activity and control groups and by gender.

No significant gender differences were observed in the changes of vertical squat jump, standing long jump or in the maximal oxygen uptake after the training programme. Women achieved greater changes after the training in 20 metre running time ($F = 10.62$, $df = 1$, $p = 0.01$), while men achieved greater changes after the training in maximal anaerobic cycling test ($F = 5.86$, $df = 1$, $p = 0.02$).

6.2. Effects of external light load vs. no load on muscle power in lower extremities (Study 1)

No significant differences were found between the light load and no load groups concerning the type of previous exercise activity, perceived health and fitness, and shoulder-neck, low back, hip, knee and ankle symptoms at the baseline (Study 1), or immediately after the intervention. No significant differences between the groups were observed in body weight after the intervention. There were no differences in exercise induced injuries between the light load and no load groups. At baseline, no differences between the groups were observed in vertical squat jump, 20 metre running time, maximal anaerobic cycling power or in maximal oxygen uptake values (Study 1). After the intervention, subjects in the light load group (with 2.2 kg external loading in ankles) improved vertical squat jump by 23% ($p = 0.03$) and maximal anaerobic cycling test by 12% ($p = 0.05$). The changes are significant compared with the no load group (16% increase in vertical squat jump and 5% increase in maximal anaerobic cycling power) (Study 1). No differences were observed in 20 metre running time between the light load and no load groups.

6.3. Measurement of trunk flexion and extension velocities (Study 2)

The analysis of the repetitive trunk muscle flexion and extension velocities at three angular phases showed that the peak velocities of the second phases of these movements (between 15° and 35° in flexion and between 20° and 0° in extension) correlated highly ($r = 0.99$) with the peak velocity of the whole

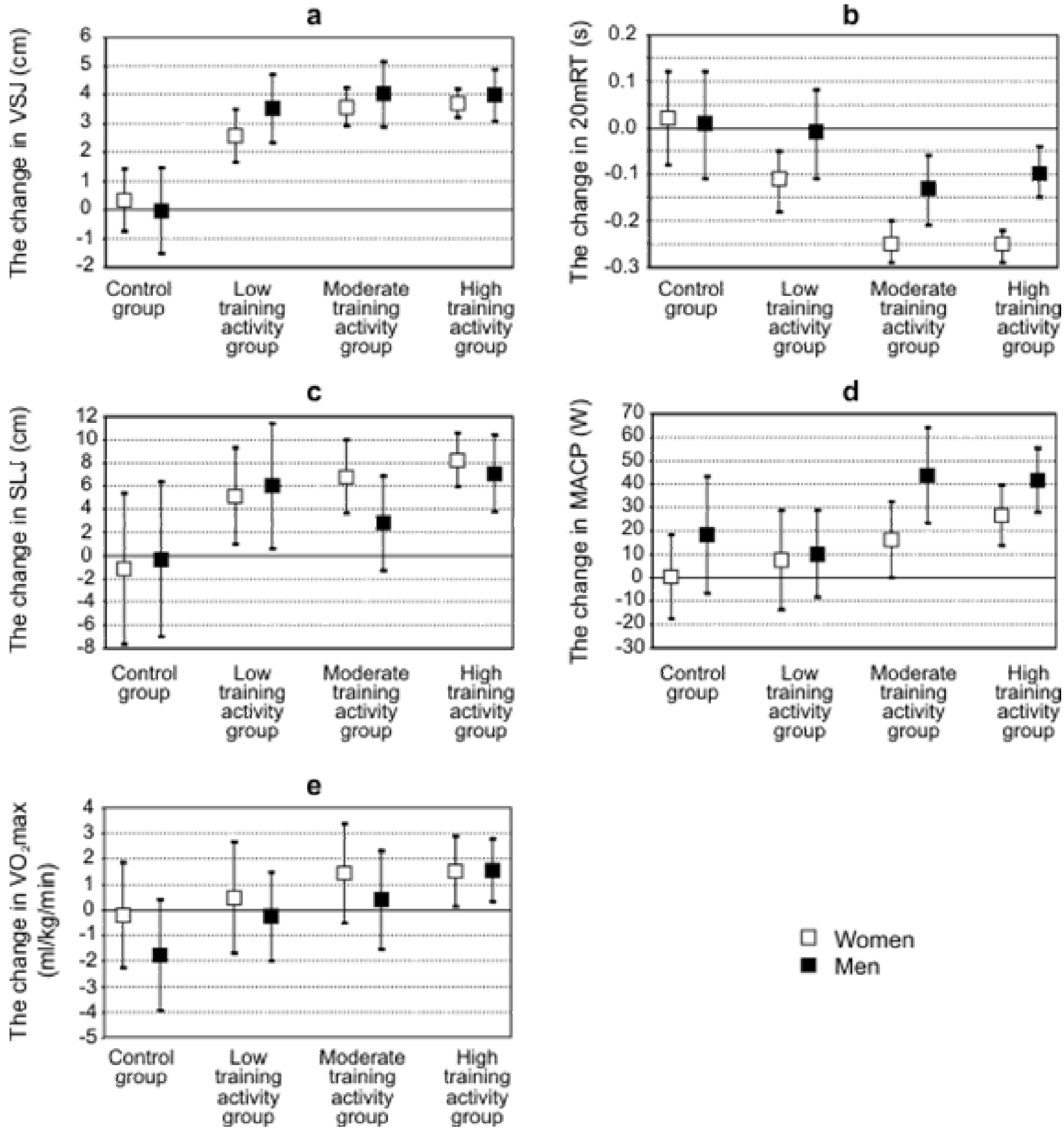

Figure 2. Mean change and upper and lower 0.95 confidence limits for men and women in three different training groups and in the control group. a) Vertical Squat Jump (VSJ), b) 20 metre Running Time (20mRT), c) Standing Long Jump (SLJ), d) Maximal Anaerobic Cycling Power (MACP), e) maximal oxygen uptake (VO_2 max).

movement (from –5° to 55° in flexion and from 40° to 20° in extension) both in flexion and extension. Correlations were high both before and after the 22-week intervention. The LISREL analysis showed high reliability in peak flexion (r = 0.78) and extension (r = 0.81) velocities between the pre- and post-intervention values (Study 2).

6.4. Effects of power-type strength training on trunk muscle performances (Study 3)

The age, weight and height or lumbar spine measurements at baseline of women and men did not differ between the groups (Study 3), and no difference between the groups were found in self-reported low back symptoms, perceived health and fitness, physical activity and smoking at baseline (Study 3).

Differences were observed in training induced changes of peak flexion velocity between the female and male high training groups vs. female ($F = 7.54$, $p = 0.008$) and male ($F = 4.86$, $p = 0.03$) low training groups, and in peak extension velocity correspondingly ($F = 9.07$, $p = 0.003$ for women, and $F = 12.31$, $p = 0.001$ for men). The training induced change in peak flexion velocity was 13 deg/s greater both in the female and male high training groups than in the corresponding low training groups ($p < 0.05$). The change in peak extension velocity was 15 deg·s^{-1} higher in the female high training group than in the female low training group ($p < 0.05$), and 18 deg·s^{-1} higher in the male high training group than in the male low training group ($p < 0.05$).

6.5. Effects of training on perceived health and fitness (Study 4)

Both male and female exercisers perceived that their physical fitness improved ($p < 0.01$ for men and $p < 0.0001$ for women) during the intervention period. Perceived physical health improved in female exercisers only ($p < 0.001$).

The male dropouts showed a significantly poorer perceived health than the exercising men ($p < 0.01$). Men attended 62 ± 23% (mean ± SD) and women 66 ± 18% of the scheduled training sessions. Twelve men and 25 women attended 80% or more of the scheduled training sessions. Those with a training attendance ≥ 50% showed improved perceived fitness; in women the change was significant ($p < 0.05$). While significant improvements occurred in perceived physical fitness (men and women) and in perceived physical health (women), the control subjects (n = 18) did not show any changes in either of these variables.

Men with improved vertical squat jump performance showed improved perceived health ($p < 0.05$) and women with improved standing long jump performance showed increased perceived fitness ($p < 0.05$). No such trends were observed in the controls.

6.6. Knee and low back symptoms, and training induced injuries during the intervention (Study 4)

In exercisers the number of men reporting no low back or knee symptoms increased from 20 at the baseline to 25 after the intervention, and in women the corresponding values were 49 and 55. The frequency of low back symptoms decreased by 13% ($p = 0.06$) in men and by 10% ($p = 0.06$) in women. Knee symptoms increased by 2% ($p = 0.8$) in men and by 5% ($p = 0.35$) in women. Among the controls, low back symptoms decreased by 11% and knee symptoms increased by 6%. Exercising men who reported more knee symptoms after the intervention had higher body mass index (28 ± 3, $p < 0.05$) than men on average (26 ± 3). The same was not observed in women. Of those participants who had no knee symptoms before the intervention, 17% reported symptoms in their knees during the programme, and 14% of the participants who had knee symptoms before the intervention reported after the programme that their symptoms had relieved.

The injury rate during training sessions was on average 10% (n = 16); 19% for men (n = 10) and 6% (n = 6) for women. The injuries included non-specific knee pain (19%), sprain or strain in thigh (37%) and calf muscles (13%), twisted ankle (19%), muscle cramp in low back (6%) and strained shoulder muscles (6%). Five participants sustained overuse injuries during the intervention, including non-specific knee pain (n = 2), low back pain (n = 2) and pain in calf muscle (n = 1).

6.7. Adherence to training programme (Study 5)

The analysis of the data concerning all the participants (n = 226) who started to exercise showed that the training activity was associated with unemployment ($F = 15.2$, $p < 0.0001$), smoking ($F = 5.21$, $p = 0.02$) and age ($F = 3.88$, $p = 0.05$) with the younger subjects having lower adherence to the programme. No association was observed between training activity and gender, body mass index, shoulder, neck, low back, knee or ankle symptoms, perceived health or fitness. Twenty-two of the dropouts interrupted because of lack of motivation, 18 because of lack of time, 8 because of an exercise induced musculoskeletal symptom, and 7 because of other reasons.

The subjects' age and body mass index, the distribution of smoking, previous and present physical exercise activity, the rate of physical leisure activity, perceived health, perceived fitness and musculoskeletal symptoms are presented in Table 2 for men and in Table 3 for women.

Of all female smokers 57% dropped out of the training programme, while only 15% of female non-smokers dropped out ($p < 0.05$). Of all female participants the unemployed women smoked significantly more ($p < 0.01$); this was not observed in men.

Among the subjects in age groups < 40 years, 40-49 years and ≥ 50 years who completed the training programme, the significantly lowest training attendance (%) was found in women under 40 years of age (58 ± 19%) ($p < 0.05$). The attendance rate was 66 ± 19% in women ≥ 50 years and 69 ± 16% in women aged 40-49 years.

The overall unemployment rate was 21%. The unemployment rate was 47% among the dropouts, while it was 8% in high training, 16% in moderate training and 17% in low training groups. Nineteen (19) percent of dropouts perceived their fitness good, whereas 48% of exercisers had good perceived fitness ($p = 0.02$). Most of the subjects trained both for physical and mental well-being (approximately 43%), the second frequent motive for physical training was mental well-being (approximately 25%).

7. DISCUSSION

7.1. Training effects on leg muscle performances

The power-type strength training programme was effective in improving the middle-aged participants' physical performances requiring explosive muscle force, expressed here by the vertical squat jump, 20 metre running time, standing long jump, and their maximal anaerobic cycling power. The changes are comparable with previous studies (Kaneko et al., 1983; Wilson et al., 1993; Aagaard et al., 1994). In a study of Häkkinen and Komi (1985), the measured jumping height increased by 21% in well-trained young men who trained progressively mainly jumping exercises for 24 weeks. In a study of Judge et al. (2003) in highly skilled athletes, the increase in rapid isometric knee extension was 24% after a 16-week sport-specific resistance training, and in a study of Delecluse et al. (2003) in young untrained women, 12 weeks of moderate resistance training (10–20 repetition maximum) increased the dynamic knee extension strength by 7%, but the explosive strength (measured by countermovement jump height) remained unchanged.

In the present study, the enhancements attributable to the power-type strength training were similar in men and women, except for 20 metre running time where no change was observed in the male low training activity group. Women's results tended to show higher improvements in vertical squat jump. Women in training groups showed lower baseline values than the female controls, and it is known that, when they start to exercise regularly, less fit people achieve higher gains in comparison with well-trained individuals measured by most of the indices of physical fitness (Blair et al., 1996; Winters-Stone and Snow, 2003). This may be one of the explanations for the higher changes in women in the present study.

Greater improvements would probably have been achieved in standing long jump, if the training had resembled more the test performance. In addition to this training specificity effect, standing long jump demands flexibility, and also certain performance technique. Perhaps greater attention should have been paid to the flexibility training to reduce muscle stiffness and increase the elasticity. It can be assumed that the middle-aged and mostly sedentary participants to this study were initially within the normal range or below the average in terms of flexibility, and further, it can also be assumed that they had no practice in the standing long jump technique, neither before nor during the intervention programme. Ageing and sedentary lifestyle leads to a decline in the function of the tendons and decreased strength of the joints (Kannus and Jozsa, 1991; Vailas and Vailas, 1994; Tuite et al., 1997), and consequently, flexibility exercises are important for reducing the stiffness of the muscles (Wilson et al., 1991).

The electromyographic activity was not measured in this study, but it is presumed that a great part of the enhancements, especially in vertical squat jump but also in the other physiological measurements, were due to the neuromuscular adaptation (Moritani and DeVries, 1979; Häkkinen, 1994). Cronin et al. (2000) also stressed the importance of the adaptation of the neuromuscular system in concentric muscle actions that require higher rates of initial power production, such as vertical squat jumps.

7.2. Impact of light loading on muscle power in lower extremities

One of the aims of the study was to investigate the impact of light external loading on the training effect in leg muscles. The results show that an external loading totalling 2.2 kg in ankles improved the jumping height and maximal anaerobic cycling power, but not the sprint running performance. If the training programme had been carried out with heavier weights and with individually determined progressions of loading, greater improvements would probably have been achieved. For over 20 years ago, Komi et al. (1982) showed that power-type strength training without external resistance leads only to minor increases in the size of fast-twitch muscle fibres.

All the subjects in the light load group used the same total loading of 2.2 kg during the 16 training weeks, independent of gender or body weight. The progression in our study involved increased velocity and greater effort in exercises by time period. Except for the light external loads in the light load group, the training programme was similar in contents for both groups. Mazzetti et al. (2000) compared the effects of heavy-resistance training between supervised and unsupervised training groups. The improvements were higher in the supervised group, in which the training load and progression were increased and adjusted by the supervisor. The rate of progression was probably the primary factor contributing to higher physical improvements in the supervised group, compared with the unsupervised group.

Driss and co-workers (2001) found in their study that when external loads of 5 and 10 kg were used, the instantaneous peak power in squat jump decreased in untrained subjects, but not in volleyball players and weight-lifters. The authors suggested that vertical jump height was associated with previous training activity, and similarly, in sprint running the running technique may also be related to previous running activity.

The use of light loads in the present study had an impact on jumping height, but not on the 20-metre sprint performance. In a study by McBride et al. (2002), the men who exercised with loads corresponding to 30% of their repetition maximum increased their jumping height significantly more than the men who trained with loads corresponding to 80% of repetition maximum. The loads were heavier than in the present study, but the trend is similar. However, in the study of McBride et al. (2002) there was no significant difference between the groups in 20 m sprint running time.

Cronin et al. (2000) pointed out the importance of maximal strength in initial power production in stretch-shortening cycle actions, but according to the authors, the adaptation of the neuromuscular system was even more important in concentric muscle actions that require higher rates of initial power production, such as vertical squat jumps. On the other hand, Stone et al. (2003) found in their study that strength training with lighter loads (between 10% - 40% of one repetition maximum) and squat jump had high correlations (ranging from $r = 0.84$ to $r = 0.90$). The authors concluded that strength training with loads from 10% to 40% of one repetition maximum is the primary component in improved jumping height. This finding is supported by the study of Moss et al. (1997), in which they measured the elbow flexor strength, power and angular velocity and found that performance velocity increases at submaximal level when maximal strength increases.

Both strength training and high-velocity training are needed for sprint running, and according to Delecluse (1997), high-velocity training is particularly effective in enhancing the acceleration phase at the beginning. In the present study, 5 metres only were omitted from the calculation of the 20 m sprint running performance. Therefore, it is highly probable that part of the acceleration phase was actually included in the measurement. The distance of 20 metres for sprint running was chosen because the aim was to explore possible increase of maximal leg muscle power. Including the end of the acceleration phase in the measurement, this distance was supposed to be a more sensitive measure than running a distance at maximal running speed (in which case the distance should have been at least 30 m). With a longer maximal running phase, the leg muscle power might be concealed by a poor running technique in sedentary subjects.

Sprint running perhaps needs more practice in elementary running technique, and the use of loads is of minor relevance when middle-aged, sedentary "beginners" are exercising. When untrained subjects in a study of Mero and Komi (1985) were towed to supramaximal running speed (above their normal maximal speed), they were unable to increase the stride rate, and instead, they responded to increased speed with inefficient increase of stride length. Well-trained athletes succeeded to increase both stride rate and stride length in the said study. This difference in running techniques between untrained and trained individuals indicates that with sprint exercise (supramaximal exercises) it is possible to adapt human neuromuscular performance to a higher level.

The explosive force production increased markedly in leg muscles, as suggested by the significant changes in vertical squat jump. The vertical squat jump performance demands only concentric muscle work, and no stretch-shortening cycle occurs. The smaller improvements in 20 metre running time in the previously untrained participants may also be explained by the lack of elasticity, as well as protective mechanisms in muscles and tendons in trying to avoid injuries. In sprint running the effect of elastic properties and the function of tendons is of greater importance than in vertical squat jump. The role of protective mechanism is supported by the finding of Schmidtbleicher and Gollhofer (1982) that, in drop jump exercises from varied heights untrained subjects responded with an inhibition (reduced agonist muscle activity) during the stretch load phase (eccentric), while trained subjects reacted with a facilitation (increased agonist muscle activity). A reduction in the electromyographic activity before the ground contact has been observed in untrained subjects, and this is suggested to be a protective mechanism by the Golgi tendon organ reflex, acting during sudden stretch loads (Gollhofer, 1987; Schmidtbleicher, 1988).

In the present study, all of the participants might have achieved higher absolute results in performance tests with a more sufficient warming-up before the tests. In a recent investigation of Gourgoulis et al. (2003), the vertical jump ability increased by over 2% after a proper warming-up before the performance test, and the subjects with high initial strength improved their jump ability by 4%. The warming-up effect probably has similar effects in other performance tests requiring explosive force as well.

7.3. Reliability of the trunk velocity measurement

The reliability of trunk muscle velocity measurement between interventions was high. In the trunk flexion and extension movements, the purpose was to achieve the highest velocities possible. In order not to compromise the reliability of the measurement, the resistance was set at 20% of the individual maximal isometric torque. In previous studies, resistances between 30% and 70% of isometric maximum have been used for achieving good reproducibility (Parnianpour et al., 1989; Rytökoski et al., 1994). The angular phases from 15 to 35 degrees in flexion and from 20 to 0 degrees in extension represented the peak velocity of the whole movement, and thus, a reliable peak value of flexion and extension velocity can be achieved at a narrow angular phase of 20 degrees. The LISREL analysis reflected the way of performing the movement: the faster the start the slower the end, and vice versa.

7.4. Training effects on trunk muscle performances

The training resulted in significant improvements in trunk flexion (14%) and extension (16%) velocities in all exercisers. The results indicate that the design and progression of the programme were successful for the purpose of achieve improved trunk muscle velocity in sedentary middle-aged subjects, in spite of the fact that the training mainly focused on lower extremity muscles (40% trunk exercises and 60% leg muscle exercises).

In the present study, the various training subfields (basic strength training and co-ordination skills, strength training, and power-type strength training) were not mixed with each other during the same training period. Häkkinen et al. (1998) found that a training programme that was composed of a mixture of exercises increasing muscle mass, maximal force, and explosive strength led to significant gains in maximal isometric force, but not in velocity properties. The authors attributed this to the mixture of three different performances, with too little effort on developing the explosive strength.

After the training intervention, the subjects with a training frequency of at least twice a week achieved significant improvements in the peak velocity of the trunk flexion and extension, when compared with subjects who trained once a week or less. This is an important piece of information for establishing the dose-response effect of power-type strength training. The finding is in line with a previous study by DeMichele et al. (1997) in which the relative improvement in torso rotation strength was highest in the group that trained 2 times a week. In the said study, the differences were not significant between the groups training 2 times or 3 times a week, but the subjects who trained 3 times a week complained more about minor muscle soreness and fatigue than those who trained once or twice a week. This may have influenced the higher improvements in the results of the group that trained twice a week.

On the other hand, Graves et al. (1990) suggested that as low a training frequency as once a week was effective enough to improve isolated lumbar spine extension strength, and Pollock et al. (1989) demonstrated that lumbar extensor muscles have large potential for strength improvements. Also, the strength and power are usually 30% greater in trunk extension than flexion in most conditions (Beimborn and Morrissey, 1988). However, DeMichele et al. (1997) and Graves et al. (1990) applied the same apparatus and procedures both in training and testing, whereas in the present study the movements in actual training and during the measurement sessions differed from each other. Several studies (Baker et al., 1994; Morrissey et al., 1995; Murphy et al., 1994; Scutter et al., 1995; Wilson et al., 1996; Judge et al., 2003) have shown a better transference of training gains to the measurement situation when the movement velocity, resistance, subject's position during performance, and type of muscle contraction in trunk exercises are as similar as possible.

Trunk muscles should be trained by various types of exercises (aerobic, strength and power-type strength training) in order to provide many-sided and sufficient stimulus and loading for trunk muscles. Therefore, for achieving this goal, power-type strength training should also be included in the training programs designed for the middle-aged and even elderly people. Training frequency is an important factor in the prescription of exercise for healthy subjects, who may benefit from power-type strength training through a reduced risk of low back disorders or low back pain.

7.5. Feasibility of power-type strength training in middle-aged men and women

The injury rate in the present study was 19% in men and 6% in women. The rates are relatively low, considering the training mode, i.e. explosive exercises with maximal effort. Higher injury frequencies have even been encountered in endurance sports (Koplan et al., 1982; Blair et al., 1987). Any interruptions in training due to musculoskeletal symptoms and injuries were short, suggesting that the disorders and injuries were not serious. On the other hand, all training sessions in the present study were controlled and supervised, whereas endurance sports are usually practised individually without guidance. The higher injury rate among men in the present study was in line with a survey of exercise-related injuries by Uitenbroek (1996).

Muscle strains occurred mainly during sprint or step-aerobic exercising and twisted ankles during jump or sprint exercising, whereas overuse symptoms and disorders in knees, leg muscles and low back muscles were mostly caused by sprint or jumping exercises. As mentioned before, the training programme was supervised, which counterbalanced and perhaps prevented injuries, in spite of the fact that the participants – middle-aged, mostly sedentary men and women – are a risk group for injuries (Van Mechelen, 1992). The cornerstones of the training were throughout the intervention sufficient warming-up before training, muscle stretching after training, not too fast progressing intensity, variation in training sessions, and finally, no competitive elements were included in the training programme.

Women rated both their perceived health and fitness and men their perceived fitness better after the intervention. The fact that low back and knee symptoms did not show any increase after the training programme, certainly has contributed to the increase in self-rated health and fitness among the participants. Participation in an intensive training programme may have influenced the exercisers' subjective perception of health and fitness; after the intervention many participants probably felt healthier and more fit than before because of a change in lifestyle, even if the change were temporary. Similar effects of participation in fitness programmes have been previously reported (Shephard and Bouchard, 1995; Sörensen et al., 1997). The positive feedback concerning health and fitness in this study was in line with previous observations (Allison, 1996; Manderbacka et al., 1999), indicating that health behaviours are associated with self-rated health; subjects with low physical activity at leisure, and with unhealthy dietary habits, as well as smokers show poorer self-rated health.

In a recently published study of Anton et al. (2004), the authors gave support to the hypothesis that the age-related decline is greater in the more complex performances which require more of power-type strength and greater neuromuscular co-ordination. Therefore, in designing training programmes for middle-aged and even older subjects, the participants' current health status, training status, physical activity and previous training background will give valuable information for the purpose of making up an optimal training programme with relevant training intensity for the target group, and thereby preventing exercise induced injuries and musculoskeletal symptoms. This background information also assists the training instructor in individually optimising the intensity and progression of the programme.

7.6. Adherence to the training programme

Although the power-type strength training programme was initially unfamiliar and demanding in terms of intensity for most of the participants, the dropout rate in the present study was low, when compared with other studies, as reviewed by Robison and Rogers (1994). The dropout rate was greatest during the first weeks, which is in line with several earlier studies, as analysed by Dishman and Buckworth (1996). In the present study, one possible explanation for dropping out at an early stage is the discrepancy between the subject's own, probably unrealistic expectations of training and the actual training with all its potential inconvenient side effects. The discrepancy between the actual exercising and the image of exercising may also be of practical nature, e.g. the lack of time, the lack of means of transportation, and the family-related demands certainly have an effect on training adherence.

The low training adherence among the unemployed was an interesting finding in the present study. Unemployment may reduce a subject's capacity to meet these different types of problems. Possibly reduced capacity to handle problems is supported by a large empirical study of Whooley et al. (2002) in which depressive symptoms were associated with subsequent unemployment and loss of income. Unemployment can be a powerful stressor (Ezzy, 1993). Physical exercise has been shown to reduce anxiety in unemployed (Grönningsäter and Fasting, 1986), therefore it is important to encourage the unemployed to adopt and maintain regular physical exercising. In the present study, the unemployed smoked more than the employed, and the unemployed dropouts smoked more and had more frequent knee symptoms than the unemployed who completed the training programme. The unemployed showing good adherence to the programme also perceived their fitness and health better.

The higher training adherence among older participants may be explained by the fact that they had more time to spend in physical activities, and perhaps also a more realistic picture of their own capacity to complete the intervention programme. The latter aspect may partly explain why younger female participants had lower adherence to this programme. Evenson et al. (2002) suggested that the perimenopausal period is a critical time at which focused and tailored physical interventions may help women to adopt physical activity patterns from the earlier periods of life in order to be physically active in postmenopausal period.

With increasing age, health-related problems begin to appear and individuals start paying more attention to health issues. In general, the most common exercise motives both in men and women are those connected to health and fitness. Women are more often than men motivated by health and stress reduction, and ageing adults seem to be more interested in exercising for stress reduction and social reasons (Duda and Tappe, 1989; Dishman, 1993).

Male dropouts presented a lower rate of physical leisure activities than the men who completed the programme; the most popular exercise and leisure activities were walking, home gymnastics and gardening. Probably subjects with these light and moderate activities had already done their contemplation of the exercise (Prohaska and Clemente, 1983) and were better prepared for the intervention programme, which in turn resulted in higher training adherence.

The exercisers more frequently trained for mental satisfaction, compared with the dropouts; otherwise the training motives were similar for all groups and both genders. It can be assumed that achieving mental well-being in connection with physical training needs previous positive physical and mental experiences. This may be reflected in the better adhering participants' answers concerning their motives. The training motives may be linked with the reasons given by the dropouts, such as "lack of motivation" and "lack of time". To be motivated to train physically, one needs to internalise the subjective benefits.

There were no differences in health or in musculoskeletal symptoms between the exercisers and dropouts. Therefore, the main reasons for their different adherence behaviour are probably the present physical activity at leisure, the perception of one's own health and fitness, and the socio-economical status. When interpreting the results of this study, one must also take into consideration that many factors that are essential for the evaluation of the reasons for dropping out were not included in the study, for example, education, level of income, marital status, children and several other environmental factors. Previous studies indicate that exercise adherence is lower among people with low education and low income (Yen and Kaplan, 1998; Trost et al., 2002).

7.7. General evaluation of the study

The subjects in this study were heterogeneous concerning employment status; both blue-collar and white-collar professions were represented (majority of participants were engaged in light office work), the age among subjects ranged from 29 to 69 years, and the exercise history also varied greatly. Most of the participants were sedentary when the intervention started and had been so for years. The type of training used in the intervention is very demanding for the neuromuscular system, and therefore it is important to keep the (duration of) exercise bouts short and take care of sufficiently long recovery times (at least 2–4 minutes). These criteria were difficult to meet in the training programme for practical reasons: training was conducted in exercise classes of 10–20 subjects, with differing individual training experience and status within each exercise class. The recovery times were for some of the subjects almost always too short.

The evidence of the intervention would have been more powerful if the study population had been randomised. However, randomisation would have been very difficult in this study in which the subjects were asked to perform physical exercises with maximal effort. Volunteers in physical training programmes usually have a positive approach, but the subjects may also have expectations concerning the effort they have made, and this may cause a bias, compared with the non-training controls, who may have quite opposite attitudes to physical strain.

The number of non-training controls should have been greater in this study. The small number of non-training controls does not allow any larger generalisations. As a matter of fact, a kind of simple group-wise randomisation took place when the population was divided into No Load versus Light Load groups; before the training started, the participants did not know whether they would have external loads totalling 2.2 kg in their ankles or not during the power-type strength training periods.

At baseline, the subjects were similar in anthropometrical, some behavioural, and habitual characteristics, and also in the distribution of low back symptoms. However, the classification of participants according to the attendance rates is a limitation of the study, because some unmeasured characteristics of those with high and those with low attendance rates may have been missed. It can be assumed that subjects with high adherence were more motivated to try harder and achieve higher improvements in measurements. This sub-grouping of the subjects may also have caused some disadvantages. The number of subjects in some sub-groups became small, resulting in a lower statistical power. Sub-grouping was justified by the fact that the participants adhered differently to the training, and by the aim of investigating the outcome of exercise dose vs. response.

Unfortunately, the subjects did not keep a diary of their physical activities besides the training programme. That would have been very helpful for achieving greater accuracy of the training dose versus response analysis. As it now stands, the minimum training dose is known, but the dose vs. response is not accurate in those participants who exercised in their leisure time more than the programme required.

The effects of power-type strength training were measured by numerous and various methods, including semi-objective and subjective measurements. This was done for obtaining a comprehensive picture of the changes after the power-type strength training intervention, not only changes in leg and trunk muscle performances. The measurement methods used in this study were all validated: vertical squat jump (Bosco et al., 1982; Moir et al., 2004), 20 metre running time (Mero et al., 1981; Delecluse, 1997; Moir et al., 2004), maximal anaerobic cycling test (Rusko et al., 1993; Rusko and Nummela, 1996; Nummela, 1996) and standing long jump are widely used in testing physical performance, especially among sports athletes. Also, the questionnaires on perceived health, fitness and physical activity, and musculoskeletal symptoms (Kuorinka et al., 1987, Moum, 1992; Wolinsky and Johnson, 1992) have been shown to be valid. All possible interfering factors were, however, not included in the study. After the initial measurements, the subject should have been measured again after four weeks, before the training started, for controlling the effects of the measurement. Muscle strength for the leg muscles should have been included in the measurements, as it was done for the trunk muscles. The leg muscle strength would have been a reference parameter for the various power-type strength measurements of leg muscles. Also, participants should have been measured approximately six weeks after the training started for controlling the neural effects in performances. Training in exercise classes was supervised by the one and the same instructor, and there were three to four exercise classes training simultaneously.

This research was needed for planning and designing training programmes that are both sufficient in intensity for achieving training effects and safe enough to keep exercise induced injuries and musculoskeletal symptoms at a low level. It was also important to find out what are the motives of middle-aged, sedentary men and women to exercise and by what means their exercise adherence could be maintained. The daily activities of the subjects in this target group often include little of physical activities both at work and at leisure. Further, the combination of sedentary lifestyle with normal ageing process will inevitably decrease their functional capacity, and various diseases may appear with increasing age and sedentary lifestyle.

For further research, the effects of power-type strength training should be investigated preferably by randomised controlled trials. Also, it should be examined whether the intensity of this type of training could be increased in sedentary, middle-aged subjects without increasing the injury risk or musculoskeletal symptoms. The motivation for training in higher intensity programmes should also be considered.

8. CONCLUSIONS

The main conclusion of this study is that power-type strength training is to be recommended for middle-aged men and women. The training effect seems to be sufficient; training frequency should be at least twice a week for achieving visible training effects. The training programme presented here is simple and practical to carry out among middle-aged, sedentary people. The outcome of this study may be of assistance in planning and designing training programmes for middle-aged and even older subjects. With increasing age, rapid force production is important for the performance of daily activities and also, e.g., in preventing of falling.

In addition, the study shows that training improves power-type strength performances in leg muscles, and a small progression with light external loads (totalling 2.2 kg) in ankles increases the efficiency, especially in vertical squat jump and in anaerobic capacity of leg muscles. The improvements in other performances than those mentioned were moderate.

The trunk muscle flexion and extension measurement proved to be a reliable method for assessing the maximal angular velocity of the trunk muscles. This intervention indicates that power-type strength training improves the angular velocity of trunk flexion and extension, provided that the training frequency is at least twice a week.

As a whole, this study showed the feasibility of group based power-type strength training for sedentary middle-aged men and women. Perceived health and fitness increased among the subjects who completed the training programme. The relatively low incidence of training induced injuries and the unchanged or decreased level of musculoskeletal symptoms during the training indicate the feasibility of the programme.

The adherence to the programme was acceptable, especially among women older than 50 years, among the employed men and women, and among the non-smokers. The main reasons for dropping out were lack of motivation and lack of time. The subjects who completed the programme perceived their fitness and health better after the training programme.

9. REFERENCES

Aagaard, P., Simonsen, E.B., Trolle, M., Bangsbo, J. and Klausen, K. (1994) Effects of different strength training regimes on moment and power generation during dynamic knee extensions. *European Journal of Applied Physiology* **69,** 382-386.

Aagaard, P., Simonsen, E.B., Andersen J.L., Magnusson, P. and Dyhre-Poulsen, P. (2002) Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology* **83,** 1318-1326.

Abenheim, L., Rossignol, M., Valat, J.-P., Nordin, M., Avouac, B., Blotman, F., Charlot, J., Dreiser, R., Legrand, E., Rozenberg, S. and Vautravers, P. (2000) The role of activity in the therapeutic management of low back pain. *Spine* **25,** 1S-33S.

Akima, H., Kano, Y., Enomoto, Y., Ishizu, M., Okada, M., Oishi, Y., Katsuta, S. and Kuno, S. (2001) Muscle function in 164 men and women aged 20-84 yr. *Medicine and Science in Sports and Exercise* **33,** 220-226.

Allison, K.R. (1996) Predictors of inactivity: An analysis of the Ontario health survey. *Canadian Journal of Public Health* **87,** 354-358.

American College of Sports Medicine. (1998) *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription*. 3rd Ed. Baltimore: Williams and Wilkins. 448-455.

Aniansson, A., Grimby, G., Hedberg, M. and Krotkiewski, M. (1981) Muscle morphology, entzyme activity and muscle strength in elderly men and women. *Clinical Physiology* **1,** 73-86.

Anton, M.M., Spirduso, W.W. and Tanaka, H. (2004) Age-related declines in anaerobic muscular performance: weightlifting and powerlifting. *Medicine and Science in Sports and Exercise* **36,** 143-147.

Asmunssen, E. and Heeboll-Nielsen, K. (1962) Isometric muscle strength in relation to age in men and women. *Ergonomics* **5,** 167-169.

Baker, D., Wilson, G.M. and Carlyon, B. (1994) Generality versus specificity: a comparison of dynamic and isometric measures of strength and speed-strength. *European Journal of Applied Physiology* **68,** 350-355.

Bassey, E.I., Fiaratore, M.A., O'Neill, E.F., Kelly, M., Evans, W.J. and Lipsitz, M.A. (1992) Leg extensor power and functional performance in very old men and women. *Clinical Science* **82,** 321-327.

Behm, D.G. and Sale, D.G. (1993) Velocity specificity of resistance training. *Sports Medicine* **15,** 374-388.

Beimborn, D.S. and Morrissey, M.C. (1988) A review of the literature related to trunk muscle performance. *Spine* **13,** 655-660.

Bemben, M.G., Massey, B.H., Bemben, D.A., Misner, J.E. and Boileau, R.A. (1991) Isometric muscle force production as a function of age in healthy 20- to 74-yr-old men. *Medicine and Science in Sports and Exercise* **23,** 1302-1310.

Biering-Sorensen, F. (1983) A prospective study of low back pain in a general population. II. Location, character, aggravating and relieving factors. *Scandinavian Journal of Rehabilitation Medicine* **15,** 81-88.

Bij, A.K., Laurant, M.G.H. and Wensing, M. (2002) Effectiveness of physical activity interventions for older adults. A review. *American Journal of Preventive Medicine* **22,** 120-133.

Blair, S.N., Kohl, H.W. and Goodyear, N.N. (1987) Rates and risks for running and exercise injuries: Studies in three populations. *Research Quarterly for Exercise and Sport* **58,** 221-228.

Blair, S.N., Kampert, J.P., Kohl, H.W. III, Barlow, L.E., Macera, L.A., Paffenberger, R.S. and Gibbons, L.W. (1996) Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *The Journal of The American Medical Association* **276,** 205-210.

Blazevich, A.J. and Jenkins, D.G. (2002) Effects of the movement speed of resistance training exercises on sprint and strength performance in concurrently training elite junior sprinters. *Journal of Sports Sciences* **20,** 981-990.

Borg, G. (1982) Ratings of perceived exertion and heart rates during short-term cycle exercise and their use in a new cycling strength test. *International Journal of Sports Medicine* **3,** 153-158.

Bosco, C., Ito, A., Komi, P.V., Luhtanen, P., Rahkila, P., Rusko, H. and Viitasalo, J.T. (1982) Neuromuscular function and mechanical effeciency of human leg extensor muscles during jumping exercises. *Acta Physiologica Scandinavica* **114,** 543-550.

Bosco, C., Luhtanen, P. and Komi, P.V. (1983) A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology* **50,** 273-282.

Bouchard, C., Shephard, R.J. and Stephens, T. (1994) *Physical activity, fitness and health: International proceedings and consensus statement.* Champaign, Ill: Human Kinetics Publishers Inc. 569-915.

Bravo, G.P., Gauthier, P., Roy, M., Payette, H., Gaulin, P., Harvey, M., Peloquin, L. and Dubois, M.F. (1996) Impact of a 12-month exercise program on the physical and psychological health of osteopenic women. *Journal of the American Geriatrics Society* **44,** 756-762.

Caiozzo, V.J., Perrine, J.J. and Edgerton, V.R. (1981) Training induced alterations in the force-velocity curve. *Journal of Applied Physiology* **51,** 750-754.

Caruso, C.M. and Gill D.L. (1992) Strengthening physical self-perceptions through exercise. *The Journal of Sports Medicine and Physical Fitness* **32,** 416-427.

Caspersen, C.J. and Merritt, R.K. (1995) Physical activity trends among 26 states. *Medicine and Science in Sports and Exercise* **27,** 713-720.

Caspersen, C.J., Pereira, M.A. and Curran, K.M. (2000) Changes in physical activity patterns in the United States by sex and cross-sectional age. *Medicine and Science in Sports and Exercise* **32,** 1601-1609.

Cavagna, G.A., Dusman, B. and Margaria, R. (1968) Positive work done by a previously streched muscle. *Journal of Applied Physiology* **24,** 21-32.

Cavagna, G.A., Komarek, L. and Mazzoleni, S. (1971) The mechanics of sprint running. *The Journal of Physiology* **217,** 709-721.

Cavanagh, P.R. (1988) On “muscle action” vs “muscle contraction”. *Journal of Biomechanics* **22,** 69.

Chelly, S.M. and Denis, C. (2001) Leg power and hopping stiffness: relationships with sprint running performance. *Medicine and Science in Sports and Exercise* **33,** 326-33.

Colliander, E.B. and Tesch, P.A. (1990) Effects of eccentric and concentric muscle actions in resistance training. *Acta Physiologica Scandinavica* **140,** 31-39.

Colliander, E.B. and Tesch, P.A. (1992) Effects of detraining following short term resistance training on eccentric and concentric muscle strength. *Acta Physiologica Scandinavica* **144,** 23-29.

Coyle, E., Fering, D., Rotkins T.C., Cote III, R.W., Roby F.B., Lee, W. and Wilmore, J.H. (1981) Specificity of power improvements through slow and fast isokinetic training. *Journal of Applied Physiology* **51,** 227-232.

Cronin, J.B., McNair, P.J. and Marshall, R.N. (2000) The role of maximal strength and load on initial power production. *Medicine and Science in Sports and Exercise* **32,** 1763-1769.

Delecluse, C., Coppenolle, H.V., Willems, E., Leemputte, M.V., Deils, R. and Goris, M. (1995) Influence of high-resistance and high-velocity training on sprint performance. *Medicine and Science in Sports and Exercise* **27,** 1203-1209.

Delecluse, C. (1997) Influence of strength training on sprint running performance. *Sports Medicine* **24,** 147-156.

Delecluse, C., Roelants, M. and Verschueren, S. (2003) Strength increase after whole-body vibration compared with resistance training. *Medicine and Science in Sports and Exercise* **35,** 1033-1041.

DeMichele, P.D., Pollock, M.L., Graves, J.E., Foster, D.N., Carpenter, D., Garzarella, L., Brechue, W. and Fulton, M. (1997) Effect of training frequency on the development of isometric torso rotation strength. *Archives of Physical Medicine and Rehabilitation* **78,** 64-69.

Deschenes, M.R. and Kraemer, W.J. (2002) Performance and physiologic adaptations to resistance training. *American Journal of Physical Medicine & Rehabilitation* **81 (Suppl),** S3-16.

Dishman, R.K., Sallis, J.F. and Orenstein, D. (1985) The determinants of physical activity and exercise. *Public Health Reports* **100,** 158-171.

Dishman, R.K. (1993) Exercise adherence. In: *Handbook of Research on Sport Psychology*. Eds: Singer, R.N., Murphey, M. and Tennant, L.K. New York: Macmillan. 779-798.

Dishman, R.K. and Buckworth, J. (1996) Increasing physical activity: a quantitative synthesis. *Medicine and Science in Sports and Exercise* **28,** 706-719.

Driss, T., Vandewalle, H., Quievre, J., Miller, C. and Monod, H. (2001) Effects of external loading on power output in a squat jump on a force platform: A comparison between strength and power athletes and sedentary individuals. *Journal of Sports Sciences* **19,** 99-105.

Duda, J.L. and Tappe, M.K. (1989) Personal investment in exercise among adults: The examination of age and gender-related differences in motivational orientation. In: *Ageing and motor behavior*. Ed: Ostrow, A. Indianapolis: Benchmark Press. 239-256.

Earles, D.R., Judge, J.O. and Gunnarsson, O.T. (2001) Velocity training induces power-specific adaptations in highly functioning older adults. *Archives of Physical Medicine and Rehabilitation* **82,** 872-878.

Egwu, M.O. (1996) The musculoskeletal effect of intense physical training of non-athletic youth corps conscripts. *British Journal of Sports Medicine* **30,** 112-115.

Era, P., Lyyra, A.L., Viitasalo, J.T. and Heikkinen, E. (1992) Determinants of isometric muscle strength in men of different ages. *European Journal of Applied Physiology* **64,** 84-91.

Evenson, K.R., Wilcox, S., Pettinger, M., Brunner, R., King, A.C. and McTiernan, A. (2002) Vigorous leisure activity through women’s adult life. *American Journal of Epidemiology* **156,** 945-953.

Ewing, J.L. Jr, Wolfe, D.R., Rogers, M.A., Amundson, M.L. and Stull, GA. (1990) Effects of velocity of isokinetic training on strength, power, and quadriceps muscle fibre characteristics. *European Journal of Applied Physiology* **61,** 159-162.

Ezzy, D. (1993) Unemployment and mental health: A critical review. *Social Science & Medicine* **37,** 41-52.

Feigenbaum, M.S. and Pollock, M.L. (1999) Prescription of resistance training for health and disease. *Medicine and Science in Sports and Exercise* **31,** 38-45.

Floyd, W.F. and Silver, P.H.S. (1955) The function of the erector spinae muscles in certain movements and postures in man. *The Journal of Physiology* **129,** 184-203.

Frontera, W.R., Hughes, V.A., Lutz, K.J. and Evans, W.J. (1991) A cross-sectional study of muscle strength and mass in 45- to 78 men and women. *Journal of Applied Physiology* **71,** 644-650.

Frontera, W.R., Suh, D., Krivickas, L.S., Hughes, V.A., Goldstein, R. and Roubenoff, R. (2000) Skeletal muscle fiber quality in older men and women. *American Journal of Physiology. Cell Physiology* **279,** C611- 618.

Gollhofer, A. (1987) Innervation characteristics of m.Gastrocnemicus during landing on different surfaces. In: *Biomechanics XB*. Ed: Jonsson, B. Chanpaign IL: Human Kinetics Publishers. 701-706.

Graves, J.E., Pollock, M.L., Foster, D., Leggett, S.H., Carpenter, D.M., Vuoso, R. and Jones, A. (1990) Effect of training frequency and specificity on isometric lumbar extension strength. *Spine* **15,** 504-509.

Gourgoulis, V., Aggelousis, N., Kasimatis, P., Mavromatis, G. and Garas, A. (2003) Effect of a submaximal half-squats warm-up program on vertical jump ability. *Journal of Strength and Conditioning Research* **17,** 342-344.

Grönningsäter, H. and Fasting, K. (1986) Unemployment, trait anxiety and physical exercise. *Scandinavian Journal of Sports Sciences* **3,** 99-103.

Grzywacz, J.G. and Marks, N.F. (2001) Social inequalities and exercise during adulthood: toward an ecological perspective. *Journal of Health and Social Behavior* **42,** 202-220.

Häkkinen, K. and Komi, P.V. (1983) Electromyographic changes during strength training and detraining. *Medicine and Science in Sports and Exercise* **15,** 455-460.

Häkkinen, K. and Komi, P.V. (1985) The effect of explosive type strength training on electromyographic and force production characteristic of leg extensor muscles during concentric and various strech-shortening cycle exercises. *Scandinavian Journal of Sports Sciences* **7,** 65-76.

Häkkinen, K. (1994) Neuromuscular adaptation during strength training, aging, detraining, and immobilization. *Critical Reviews in Physical and Rehabilitation Medicine* **6,** 161-198.

Häkkinen, K. and Häkkinen, A. (1995) Neuromuscular adaptations during intensive strength training in middle-aged and elderly males and females. *Electromyography and Clinical Neurophysiology* 3**5,** 137-147.

Häkkinen, K., Kallinen, K., Izquierdo, M., Jokelainen, K., Lassila, H., Mälkiä, E., Kraemer, W.J., Newton, R.U. and Alen, M. (1998) Changes in agonist-antagonist EMG muscle CSA and force during strength training in middle-aged and older people. *Journal of Applied Physiology* **84,** 1341-1349.

Häkkinen, K., Alen, M., Kallinen, M., Newton, R.U. and Kraemer, W.J. (2000) Neuromuscular adaptation during prolonged strength training, detraining and re-strength-training in middle-aged and elderly people. *European Journal of Applied Physiology* **83,** 51-62.

Häkkinen, K., Kraemer, W.J., Newton, R.U. and Alen, M. (2001) Changes in electromyographic activity, muscle fibre and force production characteristics during heavy resistance/power strength training in middle-aged and older men and women. *Acta Physiologica Scandinavica* **171,** 51-62.

Harreby, M., Hesselsoe, G., Kjer, J. and Neergaard, K. (1997) Low back pain and physical exercise in leisure time in 38-year-old women: a 25-year cohort study. *European Spine Journal* **6,** 181-186.

Helakorpi, S., Uutela, A., Prättälä, R. and Puska, P. (1998) Health behavior among Finnish adult population, Spring 1998. *Publications of the National Public Health Institute B 10: Helsinki*.

Hutten, M.M. and Hermens, H.J. (1997) Reliability of lumbar dynamometry measurements in patients with chronic low back pain with test-retest measurements in different days. *European Spine Journal* **6,** 54-62.

Isotechnologies, Inc. B-200 User's Manual. (1988) Revision 2.0, Hillsborough, North Carolina: Isotechnologies Inc., USA.

Izquierdo, M., Aguado, X., Gonzalez, R., Lopez, J.L. and Häkkinen, K. (1999) Maximal and explosive force production capacity and balance in men of different ages. *European Journal of Applied Physiology* **79,** 260-267.

Izquierdo, M., Ibanez, J., Gorostiaga, E., Garrues, M., Zuniga, A., Anton, A., Larrion, J.L. and Häkkinen, K. (1999) Maximal strength and power characteristics in isometric and dynamic actions of the upper and lower extremities in middle-aged and older men. *Acta Physiologica Scandinavica* **167,** 57-68.

Izquierdo, M., Häkkinen, K., Ibanez, J., Garrues, M., Anton, A., Zuniga, A., Larrion, J.L. and Gorostiaga, E.M. (2001) Effects of strength training on muscle power and serum hormones in middle-aged and older men. *Journal of Applied Physiology* **90,** 1497-1507.

Izquierdo, M., Häkkinen, K., Gonzalez-Badillo, J.J., Ibanez, J. and Gorostiaga, E.M. (2002) Effects of long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports. *European Journal of Applied Physiology* **87,** 264-271.

Jones, K., Bishop, P., Hunter, G. and Fleisig, G. (2001) The effects of varying resistance-training loads on intermediate - and high - velocity - specific adaptations*.* *Journal of Strength and Conditioning Research* **15,** 349-356.

Jozsi, A.C., Campbell, W.W., Joseph, L., Davey, S.L. and Evans, W.J. (1999) Changes in power with resistance training in older and younger men and women. *Journals of Gerontology Series A:*

Biological Sciences and Medical Sciences **54,** M591-M596.

Judge, L.W., Moreau, C. and Burke, J.R. (2003) Neural adaptation with sport-specific resistance training in highly skilled athletes. *Journal of Sports Sciences* **21,** 419-427.

Kanehisa, H. and Miyashita, M. (1983) Specificity of velocity in strength training. *European Journal of Applied Physiology* **52,** 104-106.

Kaneko, M., Fuchimoto, T., Toji, H. and Suel, K. (1983) Training effect of differing loads on the force-velocity relationship and michanical power output in human muscle. *Scandinavian Journal of Sports Sciences* **2,** 50-55.

Kannus, P. and Jozsa, L. (1991) Histopathological changes preceding spontaneous rupture of a tendon. *The Journal of Bone and Joint Surgery (American volume)* **73,** 1507-1525.

Kawamori, N. and Haff, G.G. (2004) The optimal training load for the development of muscular power. *Journal of Strength and Conditioning Research* **18,** 675-684.

Kemmler, W., Engelke, K., Lauber, D., Weineck, J., Hensen, J. and Kalender, W. (2002) Exercise effects on fitness and bone mineral density in early postmenopausal women: 1-year EFOPS results. *Medicine and Science in Sports and Exercise* **34,** 2115-2123.

Komi, P.V. (1973) Measurement of the force-velocity relationship in human muscle under concentric and eccentric contractions. *Biomechanics III.* Karger, Basel. 224-229.

Komi, P.V., Viitasalo, J.T., Rauramaa, R. and Vihko, V. (1978) Effects of isometric strength training on mechanical, electrical and metabolic aspects of muscle function. *European Journal of Applied Physiology* **40,** 45-55.

Komi, P.V., Karlsson, J., Tesch, P., Suominen, H. and Heikkinen, E. (1982) Effects of heavy resistance and explosive type strength training methods on mechanical, functional and metabolic aspects of performance. In: *Exercise and Sport Biology*. Ed: Komi, P.V. Champaign IL: Human Kinetics. 90.

Komi, P.V. (1984) Physiological and biomechanical correlates of muscle function: effects of muscle structure and stretch-shortening cycle on force and speed. In: *Exercise and Sports Sciences Reviews*. Vol. 12. Ed: Terjung, R.L. Lexington, Mass.:The Collamore Press. 81-121.

Koplan, J.P., Powell, K.E., Sikes, R.K., Shirley, R.W. and Campbell, C.C. (1982) An epidemiologic study of the benefits and risks of running. *The Journal of The American Medical Association* **248,** 3118-3121.

Korhonen, M., Mero, A. and Suominen, H. (2003) Age-related differences in 100-m sprint performance in male and female master runners. *Medicine and Science in Sports and Exercise* **35,** 1419-1428.

Kraemer, W.J. (1997) A series of studies: the physiological basis for strength training in American football: fact over philosophy. *Journal of Strength and Conditioning Research* **11,** 131-142.

Kraemer, W.J., Keuning, M., Ratamess, N.A., Volek, J.S., McCormick, M., Bush, J.A., Nindl, B.C., Gordon, S.E., Mazzetti, S.A., Newton, R.U., Gomez, A.L., Wickman, R.B., Rubin, M.R. and Häkkinen, K. (2001) Resistance training combined with bench-step aerobics enhances women's health profile. *Medicine and Science in Sports and Exercise* **33,** 259-269.

Kraemer, W.J., Adams, K., Cafarelli, E., Dudley, G.A., Dooly, C., Feigenbaum, M.S., Fleck, S.J., Franklin, B., Fry, A.C., Hoffman, R.R., Newton, R.U., Potteiger, J., Stone, M.H., Ratamess, R.A. and Triplett-McBride, T. (2002) American College of Sports Medicine Position Stand on progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise* **34,** 364-380.

Kujala, U.M., Viljanen, T., Taimela, S. and Viitasalo, J.T. (1994) Physical activity, VO_2max, and jumping height in an urban population. *Medicine and Science in Sports and Exercise* **26,** 889-895.

Kuorinka, I., Jonsson, B., Kilbom, Å., Vinterberg, H., Biering-Sörensen, F., Andersson, G. and Jörgensen, K. (1987) Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Applied Ergonomics* **18,** 233-237.

Kyröläinen, H., Häkkinen, K., Komi, P.V., Kim, D.H. and Cheng, S. (1989) Prolonged power training of stretch-shortening cycle exercises in females: neuromuscular adaptation and changes in mechanical performance of muscles. *Journal of Human Movement Studies* **17,** 9-22.

Lahad, A., Malter, A.D., Berg, A.O. and Deyo, R.A. (1994) The effectiveness of four interventions for the prevention of back pain. *The Journal of The American Medical Association* **272,** 1286-1291.

Lee, J.H., Ooi, Y. and Nakamura, K. (1995) Measurement of muscle strength of the trunk and the lower extremities in subjects with history of low back pain. *Spine* **20,** 1994-1996.

Lexell, J., Taylor, C.C. and Sjöström, S. (1988) What is the cause of the ageing atrophy? *Journal of the Neurological Sciences* **84,** 275-294.

Linnamo, V., Newton, R.U., Häkkinen, K., Komi, P.V., Davie, A., McGuigan, M. and Triplett-McBride, T. (2000) Neuromuscular responses to explosive and heavy resistance loading. *Journal of Electromyography and Kinesiology* **10,** 417-424.

Little, J.C. (1969) The athlete's neurosis: a deprivation crisis. *Acta Phychiatrica Scandinavica* **45,** 187-197.

Lundberg, O. and Manderbacka, K. (1996) Assessing reliability of a measure of self-rated health. *Scandinavian Journal of Social Medicine* **24,** 218-224.

Lysens, R.J., de Weert, W. and Nieuwboer, A. (1991) Factors associated with injury proneness. *Sports Medicine* **12,** 281-289.

Madsen, O.R. (1996) Torque, total work, power, torque acceleration energy and acceleration time assessed on a dynamometer: reliability of knee and elbow extensor and flexor strength measurements. *European Journal of Applied Physiology* **74,** 206-210.

Manderbacka, K. (1998) Examining what a self-rated health question is understood to mean by respondents. *Scandinavian Journal of Public Health* **26,**145-53.

Manderbacka, K., Lundberg, O. and Martikainen, P. (1999) Do risk factors and health behaviours contribute to self-ratings of health. *Social Science & Medicine* **48,** 1713-1720.

Manning, J.M., Dooly-Manning, D. and Perrin, D.H. (1988) Factor analyses of various anaerobic power tests. *Journal of Sports Medicine* **28,** 138-144.

Margaria, R., Aghemo, P. and Rovelli, E. (1966) Measurement of muscular power in man. *Journal of Applied Physiology* **21,** 1662-1664.

Marx, J.O., Ratamess, N.A., Nindl, B.C., Gotshalk, L.A., Volek, J.S., Dohi, K., Bush, J.A., Gomez, A.L., Mazzetti, S.A., Fleck, S.J., Häkkinen, K., Newton, R.U. and Kraemer, W.J. (2001) Low-volume circuit versus high-volume periodized resistance training in women. *Medicine and Science in Sports and Exercise* **33,** 635-643.

Mattila, M., Hurme, M., Alaranta, H., Paljärvi, L., Kalimo, H., Falck, B., Lehto, M., Einola, S. and Järvinen, M. (1986) The multifidus muscle in patients with lumbar disc herniation. A histochemical and morphometric analysis of intraoperative biopsies. *Spine* **11,** 732-738.

Maud, P.J. and Schultz, B.B. (1986) Gender comparisons in anaerobic power and capacity tests. *British Journal of Sports Medicine* **20,** 51-54.

Maugham, R., Gleeson, M. and Greenhaff, P.L. (1997) *Biochemistry of exercise & training*. Oxford University Press pp. 12-13.

Mazzetti, S.A., Kraemer, W.J., Volek, J.S., Duncan, N.D., Ratamess, N.A., Gomez, A.L., Newton, R.U., Häkkinen, K. and Fleck, S.J. (2000) The influence of direct supervision of resistance training on strength performance. *Medicine and Science in Sports and Exercise* **32,** 1175-1184.

Mayer, T.G., Gatchel, R.J., Kishino, N., Keeley, J., Capra, P., Mayer, H., Barnett, J. and Mooney, V. (1985) Objective assessment of spine function following industrial injury: A prospective study with comparison group and one-year follow up. *Spine* **10,** 482-493.

McBride, J.M., Triplett-McBride, T., Davie, A. and Newton, R.U. (2002) The effect of heavy- Vs. light-load jump squats on the devlopment of strength, power, and speed. *Journal of Strength and Conditioning Research* **16,** 75-82.

Mero, A., Luhtanen, P., Viitasalo, J.P. and Komi, P.V. (1981) Relationships between the maximal running velocity, muscle fiber characteristics, force production and force relaxation of sprinters. *Scandinavian Journal of Sports Sciences* **3,** 16-22.

Mero, A. and Komi, P.V. (1985) Effects of supramaximal velocity on biomechanical variables in sprinting. *International Journal of Sport Biomechanics* **1,** 240-252.

Mero, A. and Komi, P.V. (1986) Force-, EMG-, and elasticity-velocity relationship at submaximal and supramaximal running speeds in sprinters. *European Journal of Applied Physiology* **55,** 553-561.

Metter, E.J., Conwit, R., Tobin, J. and Fozard, J.L. (1997) Age-associated loss of power and strength in the upper extremities in women and men. *The Journals of Gerontology (Series A, Biological sciences and medical sciences)* **52,** B267-276.

Moffroid, M., Whipple, R., Hofkosh, J., Lowman, E. and Thistle, H. (1969) Study of isokinetic exercise. *Physical Therapy* **49,** 735-747.

Moir, G., Button, C., Glaister, M. and Stone, M.H. (2004) Influence of familiarization on the reliability of vertical jump and acceleration sprinting performance in physically active men. *Journal of Strength and Conditioning Research* **18,** 276-282.

Moritani, T. and DeVries, H.A. (1979) Neural factors versus hypertrophy in the time course of muscle strength gain. *American Journal of Physical Medicine & Rehabilitation* **58,** 115-130.

Moritani, T., Muro, M., Ishida, K. and Taguchi, S. (1987) Electrophysiological analyses of the effects of muscle power training. *Research Journal Physiology* **1,** 23-32.

Morrissey, M.C., Harman, E.A. and Johnson, M.J. (1995) Resistance training modes: specificity and effectiveness. *Medicine and Science in Sports and Exercise* **27,** 648-660.

Moss, B.M., Refsnes, A., Abildgaard, K., Nicolaysen, K. and Jensen, J. (1997) Effects of maximal effort strength training with different loads on dynamic strength, cross-sectional area, load-power and load-velocity relationships. *European Journal of Applied Physiology* **75,** 193-199.

Moum, T. (1992) Self-assessed health among Norwegian adults. *Social Science & Medicine* **35,** 935-47.

Murphy, A.J., Wilson, G.J. and Pryor, J.F. (1994) Use of the iso-inertial force mass relationship in the prediction of dynamic human performance. *European Journal of Applied Physiology* **69,** 250-257.

Narici, M.V., Roi, G.S., Landoni, L., Minetti, A.E. and Cerretelli, P. (1989) Changes in force, cross-sectional area and neural activation during strength training and detraining of the human quadriceps. *European Journal of Applied Physiology* **59,** 310-319.

Newton, R.U., Häkkinen, K., Häkkinen, A., McCormick, M., Volek, J. and Kraemer, W.J. (2002) mixed-methods resistance training increases power and strength of young and older men. *Medicine and Science in Sports and Exercise* **34,** 1367-1375.

Norris, R., Carroll, D. and Cochrane, R. (1990) The effects of aerobic and anaerobic training on fitness, blood pressure, and psychological stress and well-being. *Journal of Psychosomatic Research* **34,** 367-75.

Norvell, N. and Belles, D. (1993) Psychological and physical benefits of circuit weight training in law enforcement personnel. *Journal of Consulting and Clinical Psychology* **61,** 520-527.

Nummela, A. (1996) *A new laboratory test method for estimating anaerobic performance characteristics with special reference to sprint running*. Studies in sport, physical education and health. Academic dissertation. Jyväskylä, Finland.

Osternig, L.R., Bates, B.T. and James, S.L. (1977) Isokinetic and isometric force relationships. *Archives of Physical Medicine and Rehabilitation* **58,** 254-257.

Parnainapour, M., Li, F., Nordin, M. and Frankel, V. (1989) Reproducibility of trunk isoinertial performances in the sgittal, coronal and transverse planes*. Bulletin of the Hospital for Joint Diseases Orthopaedic Institute* **49,** 148-154.

Pate, R.R., Pratt, M., Blair, S.N., Haskell, W.L., Macera, C.A., Bouchard, C., Buchner, D., Ettinger, W., Heath, G.W., King, A.C. et al. (1995) Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *The Journal of The American Medical Association* **5,** 402-407.

Pedersen, M.T., Essendrop, M., Skotte, J.H., Jorgensen, K. and Fallentin, N. (2004) Training can modify back muscle response to sudden trunk loading. *European Spine Journal* **13,** 548-552.

Perri, M.G., Anton, S.D., Durning, P.E., Ketterson, T.U., Sydeman, S.J., Berlant, N.E., Kanasky, W.F. jr, Newton, R.L. jr, Limacher, M.C. and Martin A.D. (2002) Adherence to exercise prescriptions: effects of prescriping moderate versus higher levels of intensity and frequency. *Health Psychology* **21,** 452-458.

Pollock, M.L., Leggett, S.H., Graves, J.E., Jones, A., Fulton, M. and Cirulli, J. (1989) Effect of resistance training on lumbar extension strength. *The American Journal of Sports Medicine* **17,** 624-629.

Pollock, M.L., Gaesser, G.A., Butcher, J.D., Despres, J.-P., Dishman, R.K., Franklin, B.A. and Garber, C.E. (1998) The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Position stand. *Medicine and Science in Sports and Exercise* **6,** 975-991.

Proctor, D.N., Sinning, W.E., Walro, J.M., Sieck, G.C. and Lemon, P.W.R. (1995) Oxidative capacity of human muscle fiber types: effects of age and training status. *Journal of Applied Physiology* **78,** 2033-2038.

Prohaska, J.O. and Clemente, C.C. (1983) Stages and processes of self-change of smoking toward an integrative model of change. *Journal of Consulting and Clinical Psychology* **51,** 390-395.

Robison, J.I. and Rogers, M.A. (1994) Adherence to exercise programmes. Recommendations. *Sports Medicine* **17,** 39-52.

Ross, A., Leveritt, M. and Riek, S. (2001) Neural influences on sprint running. *Sports Medicine* **31,** 409-425.

Rusko, H., Nummela, A. and Mero, A. (1993) A new method for the evaluation of anaerobic power in athletes. *European Journal of Applied Physiology* **66,** 97-101.

Rusko, H.K. and Nummela, A. (1996) Measurement of maximal and submaximal anaerobic performance capacity: concluding chapter. *International Journal of Sports Medicine* **17,** S125-S129.

Rytökoski, U., Karppi, S.-L., Puukka, P., Soini, J. and Rönnemaa, T. (1994) Measurement of low back mobility, isoinertial performance with Isostation B-200 triaxial dynamometer: Reproducibility of measurement and development of functional indices. *Journal of Spinal Disorders* **7,** 54-61.

Sale, D.G. (1988) Neural adaptations to resistance training. *Medicine and Science in Sports and Exercise* **20,** S135- S145.

Sallis, J.F. (2000) Age-related decline in physical activity: a synthesis of human and animal studies. *Medicine and Science in Sports and Exercise* **32,** 1598-1600.

Samson, M.M., Meeuwsen, I.B., Crowe, A., Dessens, J.A., Duursma, S.A. and Verhaar, H.J. (2000) Relationships between physical performance measures, age, height and body weight in healthy adults. *Age and Ageing* **29,** 235-242.

SAS/STAT. (1989) *User's guide, version 6*. 8th edition vol. 1. SAS Institute Inc. USA.

Savinainen, M., Nygård, C.-H., Korhonen, O. and Ilmarinen, J. (2004) Changes in physical capacity among middle-aged municipal employees over 16 years. *Experimental Aging Research* **30,** 1-22.

Schmidtbleicher, D. and Gollhofer, A. (1982) Neuromuskuläre Untersuchungen zur Bestimmung, individueller Belastungsgrössen fur ein Teifsprungtraining. *Leistungssport* **12,** 298.

Schmidtbleicher, D. (1988) Muscular mechanics and nuromuscular control. In: *Swimming science V International Series Sport Science*. Eds.: Ungerechts, B.E., Wilke, K. and Reischle, K. Champaign IL: Human Kinetics. 131-148.

Scutter, S., Fulton. I., Trott, P., Parnianpour, M., Grant, R. and Brien, C. (1995) Effects of various isoresistive training programmes on trunk muscle performance. *Clinical Biomechanics* **7,** 379-384.

Shephard, R.J. and Bouchard, C. (1995) Relationships between perceptions of physical activity and health-related fitness. *The Journal of Sports Medicine and Physical Fitness* **35,** 149-158.

Skelton, D.A., Kennedy, J. and Rutherford, O.M. (2002) Explosive power and asymmetry in leg muscle function in frequent fallers and non-fallers aged over 65. *Age and Ageing* **31,** 119-125.

Sleivert, G.G., Bachus, R.D. and Wenger, H.A. (1995) The influence of a strength sprint training sequence on multi joint power output. *Medicine and Science in Sports and Exercise* **27,** 1655-1665.

Smith, A.M. (1996) Psychological impact of injuries in athletes. *Sports Medicine* **22,** 391-405.

Sörensen, M., Anderssen, S., Hjerman, I., Holme, I. and Ursin, H. (1997) Exercise and diet interventions improve perceptions of self in middle-aged adults. *Scandinavian Journal of Medicine & Science in Sports* **7,** 312-320.

Staron, R.S. (1997) Human skeletal muscle fiber types: delineation, development and distribution. *Canadian Journal of Applied Physiology* **22,** 307-327.

Staron, R.S., Karapondo, D.L., Kraemer, W.J., Fry, A.C., Gordon, S.E., Falkel, J.E., Hagerman, F.C. and Hikida, R.S. (1994) Skeletal muscle adaptations during early phase of heavy-resistance training in men and women. *Journal of Applied Physiology* **76,** 1247-1255.

Stone, M.H., O'Bryant, H.S., McCoy, L., Goclianese, R., Lehmkuhl, M. and Schilling, B. (2003) Power and maximum strength relationships during performance of dynamic and static weighted jumps. *Journal of Strength and Conditioning Research* **17,** 140-147.

Suzuki, N. and Endo, S. (1983) A quantitative study of trunk muscle strength and fatigability in the low-back pain syndrome. *Spine* **8,** 69-74.

Trost, S.G., Owen, N., Bauman, A.E., Sallis, J.F. and Brown, W. (2002) Correlates of adults' participation in physical activity:review and update. *Medicine and Science in Sports and Exercise* **34,** 1996-2001.

Troup, J.D.G. (1986) Biomechanics of the lumbar spinal canal. *Clinical Biomechanics* **1,** 31-43.

Tsutsumi, T., Don, B.M., Zaichkowsky, L.D. and Delizonna, L.L. (1997) Physical fitness and psychological benefits of strength training in community dwelling older adults. *Applied Human Science: Journal of Physiological Anthropology* **16,** 257-266.

Tucci, J.T., Carpenter, D.M., Pollock, M.L., Graves, J.E. and Leggett, S.H. (1992) Effect of reduced frequency of training and detraining on lumbar extension strength. *Spine* **17,** 1497-1501.

Tuite, D.J., Rehnström, P.A. and O'Brien, M. (1997) The aging tendon. Scandinavian Journal of Medicine & Science in Sports 7, 72-77.

Uitenbroek, D.G. (1996) Sports, exercise and other causes of injuries: Results of a population survey. *Research Quarterly for Exercise and Sport* **67,** 380-385.

Vailas, A.C. and Vailas, J.C. (1994) Physical activity and connective tissue. In: *Physical activity, fitness and health.* Eds: Bouchard, C., Shephard, R.J. and Stephens, T. Champaign IL: Human Kinetics Publishers. pp. 369-382.

Vandewalle, H., Peres, G. and Monod, H. (1987) Standard anaerobic exercise tests. *Sports Medicine* **4,** 268-289.

Van Mechelen, W., Hlobil, H. and Kemper, C.G. (1992) Incidence, severity, etiology and prevention of sports injuries: a review of concepts. *Sports Medicine* **14,** 82-99.

Van Mechelen, W., Twisk, J., Molendijk, A., Blom, B., Snel, J. and Kemper, H.C. (1996) Subject-related risk factors for sports injuries: a 1-yr prospective study in young adults. *Medicine and Science in Sports and Exercise* **28,** 1171-1179.

Viljanen, T., Viitasalo, J.T. and Kujala, U.M. (1991) Strength characteristics of a healhty urban adult population. *European Journal of Applied Physiology* **63,** 43-47.

Whooley MA, Kiefe CI, Chesney MA, Markovitz JH, Matthews K and Hulley SB. (2002) Depressive symptoms, unemployment, and loss of income: the CARDIA study. *Archives of Internal Medicine* **162,** 2614-2620.

Wilson, G., Wood, G. and Elliot, B. (1991) The performance augmentation achieved from use of the strech-shorten cycle: The neuromuscular contribution. *The Australian Journal of Science and Medicine in Sport* **23,** 97-101.

Wilson, S.H. and Walker, G.M. (1993) Unemployment and health: A review. *Public Health* **107,**153-62

Wilson, G.J., Newton, R.U., Murphy, A.J. and Humphries B.J. (1993) The optimal training load for the development of dynamic athletic performance. *Medicine and Science in Sports and Exercise* **25,** 1279-1286.

Wilson, G.J., Murphy, A.J. and Walshe, A. (1996) The specificity of strength training: the effect of posture. *European Journal of Applied Physiology* **73,** 346-352.

Winters-Stone, K.M. and Snow, C.M. (2003) Musculoskeletal responses to exercise is greatest in women with low initial values. Medicine and *Science in Sports and Exercise* **35,** 1691-1696.

Wolinsky, F.D. and Johnson, R.J. (1992) Perceived health status and mortality among older men and women. *Journal of Gerontology* **47,** S304-S312.

Yen, I.H. and Kaplan, G.A. (1998) Poverty area residence and changes in physical activity level. Evidence from the Alameda county study. *American Journal of Public Health* **88,** 1709-1712.

Young, W., McLean, B. and Ardagna, J. (1995) Relationships between strength qualities and sprinting performance. *The Journal of Sports Medicine and Physical Fitness* **35,** 13-19.

Zhu, X.-Z., Parnianpour, M., Nordin, M. and Kahanovitz, N. (1989) Histochemistry and morphology of erector spinae muscle in lumbar disc herniation. *Spine* **14,** 391-397.

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