8. Health aspects of strength training

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Summary

The traditional view of strength training is that it provides greater strength and endurance, and is primarily used as a tool in rehabilitation of musculoskeletal injuries. In more recent years, however, interest has grown in the health-enhancing effects of strength training. The diseases where strength training's possible preventive and soothing effects are discussed include diabetes, obesity, metabolic syndrome (increased lipoproteins, blood sugar, blood pressure and waist measurement), cardiovascular disease, osteoporosis, joint and back pain as well as anxiety and depression. It has also been shown that there is a relationship between muscle strength and increased risk of premature death (1).

Strength training for the elderly has received particular attention (2). Diminished muscle function can significantly limit daily activity and increase the risk for falls and fractures among the elderly. Strength training can therefore be the type of training that must precede other exercise, such as walking, to make other physical activity possible at all. Two decades' loss of strength and muscle mass in elderly can, however, be regained within two months with strength training (3).

Recommendations

In 1990, the American College of Sports Medicine (ACSM) published one of the first general recommendations to the population regarding strength training as a part of a comprehensive exercise programme comprising aerobic fitness, strength and flexibility. This type of recommendation (guidelines/position stands) is based on scientific documentation. In association with the ACSM document, strength training achieved acceptance and the recommendation was followed by several similar documents from other health organisations.

The recommendations from ACSM and from several other organisations such as the American Heart Association, the US Department of Health and Human Services and the American Diabetes Association (2, 4–9) prescribe that strength training should be carried out at least twice a week. An exercise session comprises 8–10 different exercises for various muscle groups. Every exercise is done at least once (one set) with a load of 8–12 RM (table 1). Individuals with a chronic disease are recommended a load of 10–15 RM, in other words somewhat lighter weights with more repetitions. The weight that one can lift only once is called the repetition maximum (1 RM).

Table 1. Recommendations for strength training (indicates minimum levels) (2, 4–9).

	Set/RM*	**Number of exercises**	**Frequency (times/week)**
Health adults (beginners/inactive)	1/8–12	8–10	2
Elderly	1/10–15	8–10	2
Cardiovascular/ diabetic patients	1/10–15	8–10	2
At least one set of each exercise should be done.			

* RM = Repetition Maximum. 1 RM corresponds to the highest load that can be lifted through the entire range of motion once.

The recommendations are directed at individuals with no or very little experience of strength training. The strength gain for exercise programmes with more sets compared with one set is only marginal once training begins (7, 8, 10), but the training rapidly reaches a plateau where more sets are required to increase strength capacity further. The reason for initially only recommending one set is that it is more likely that more individuals will do the strength training programme if it is less time consuming. These factors combined form the basis of the recommendation – at least one set. A similar reasoning lies behind the recommendation; at least twice a week instead of at least three times a week.

For healthy adults with prior experience of strength training, ACSM has recently issued scientific documentation regarding more advanced strength training (6, 11), where a more varied load profile is recommended in the area of 1–12 RM and up to 4–5 exercise sessions per week.

Is strength training healthy?

Both strength (table 2) and aerobic exercise can lead to a significant improvement in health, and the two variants provide some similar and some dissimilar exercise responses over time. An important aspect is that a certain degree of muscle strength is necessary to be able to be physically active. For persons who have been physically inactive and bedridden due to illness, and who have thereby lost both strength and aerobic fitness, it is especially important to train for strength to manage the strain they meet in daily life.

1. Muscle strength, muscle mass

A few months of strength training often provides very large changes in measured muscle strength, ranging from 20–30 per cent up to several hundred per cent (12) depending on the type of exercise and evaluation methods as well as on the initial degree of fitness. Most studies indicate an increase in the muscle fibres' cross-sectional area in the magnitude of 10–60 per cent, usually around 20 per cent. Measurements of the entire muscle group's cross-sectional area with magnetic resonance imaging (MRI) or computerised tomography (CT) most often indicate an increase of around 10 per cent (13), which can depend on the extra-cellular space decreasing with exercise and consequently, the actual increase in muscle mass being underestimated with MRI and CT. It is particularly important to remember with regard to strength training that the capacity to increase strength and grow muscle is retained over the years, and muscle growth and strength improvements have even been described among 90–100 year-olds (14, 15).

Besides strength training's positive effects on muscle mass, the research of recent years has shown that food and protein intake in connection with exercise (before and especially after) are important to optimise muscle growth (16).

2. Maximal oxygen uptake and endurance

The majority of studies show that strength training does not appreciably increase maximal oxygen uptake. In spite of this, strength training can increase aerobic endurance both on an ergometer cycle and treadmill (17, 18). It has also been found that strength training decreases cardiovascular stress in the form of reduced heart rate and blood pressure when walking with weights (19). If this can be attributed to the adaptation that occurs as a result of the actual strength training, or if it is a result of one being in a condition to be more physically active in daily life due to greater strength capacity and thereby obtaining better aerobic fitness has not been established. Regardless of the cause, this is an important cardiovascular result of strength training on an individual level.

3. Metabolism and body composition

Strength training can be a significant aid for the control of body weight, body composition and energy expenditure. A prerequisite for reduced body weight and fat mass is that the daily energy expenditure increases in relation to the daily energy intake. The daily energy expenditure's two most important components are the basal metabolic rate (BMR) and energy expenditure in connection with physical activity, both spontaneous daily activity and structured physical training. The increase in the energy expenditure in direct connection with strength training is moderate. In relative numbers, the load during a session is approximately 20–50 per cent of maximal oxygen uptake (20), corresponding to 100–200 kcal (rough estimate) for a 30–40 minute session, which is approximately the same as on a walk.

The most important determinant for BMR is the body's fat-free mass, of which 60–75 per cent is muscle. Among the inactive, BMR comprises the largest component (60–75%) of the daily energy expenditure. Strength training studies show that BMR can increase by approximately 5 per cent or 100 kcal per day (3, 21) during the course of an exercise period of 3–5 months. Hunter and colleagues showed that the fat-free mass increased by 2 kg and BMR by 90 kcal per day among 70-year-old women and men after 26 weeks of strength training (45 minutes training 3 times per week) (3). A BMR increase of 90 kcal per day entails increased burning of fat by 15g per day at rest (burning 1g of fat releases 6–7 kcal), compared with expenditure before the period of training. This involves a major change over one year and illustrates the importance of just a moderate increase in BMR after a period of exercise.

The reason for this increase is believed to depend on a combination of greater muscle mass in itself (1 kg muscle has a basal metabolic rate of 10 kcal per day), greater protein synthesis and breakdown (22) and greater sympatoadrenergic activation (21). The fact that the muscle mass in itself does not appear to be able to explain the entire increase is supported by studies that show that BMR can be increased for up to 48 hours after an individual exercise session (23), that is to say BMR can increase without the muscle mass changing. However, it should be pointed out that the studies that show that BMR increases in connection with strength training, the training has been relatively comprehensive and intense (at least 3 sets per exercise session, 3 times per week). A recently published strength training study of young women (2 sets per exercise session, 3 times per week) showed no increase in BMR (25).

The most interesting finding in Hunter's study (3) was, however, that the average total daily energy expenditure increased by 240 kcal, in other words by approximately 10 per cent. This probably means that the physical activity outside the training programme increased, since the total of the BMR increase (90 kcal per day) and the energy expenditure in connection with strength training (60 kcal per day) amounted to 150 kcal per day. Another study showed a similar find among young men (24). Theoretically, one month's strength training could consequently reduce fat mass by 1 kg if the energy intake is kept constant. However, it is not self-evident that physical training increases daily energy expenditure. In fact, another study showed that daily energy expenditure was unchanged in connection with an intensive aerobic exercise programme among elderly men and women, which is likely due to spontaneous physical activity outside the exercise programme decreasing (26).

4. Insulin sensitivity

Strength training can entail improved insulin sensitivity (17, 27–30) and in some cases improved glucose tolerance and glycemic control as well (17, 29–33). The effects of strength training on glucose metabolism can probably be explained by its effects on body weight, body composition and metabolism. Quality changes in the muscles probably also contribute. For example, strength training leads to a higher proportion of type IIA fibres at the expense of type IIB fibres, in other words a change towards higher oxidative capacity and slower contraction speed (20).

5. Lipoproteins

Studies have shown that there is a connection between muscle strength and an improved lipid profile (33, 34). It has also been shown that individual strength training sessions can lead to an increase in HDL (High Density Lipoprotein, the good cholesterol) among young, untrained men (35).

6. Blood pressure

Multiple studies show that strength training can lower blood pressure (17, 29, 37, 38). A meta-analysis from 2007 shows that strength training reduces diastolic blood pressure, but not systolic blood pressure, among hypertensive persons, in other words those with high blood pressure (39). However, the results are not unambiguous. Therefore, the ACSM discourages individuals with manifest increased blood pressure from only doing strength training (40). Aerobic training is primarily recommended for blood-pressure treatment purposes or a comprehensive programme that includes both aerobic training and strength training.

7. Bone density, risk of falling, balance and flexibility

A large number of studies show that strength training increases bone density or reduces the age-related decrease and that the effect is relatively specific to the muscles and parts of the skeleton to which muscles attach (41–43). Significantly more studies are done on women, due to osteoporosis (brittle bones) being much more commonly occurring particularly among elderly women. The risk of fractures of the neck of the femur doubles every five years after the age of 50 and one out of three women aged 80 break the neck of the femur (17). The increases in bone density observed after both strength training and, for example, aerobic training are, however, most often less than 5 per cent, and it is claimed that the increase in bone density should be greater to prevent fractures from falling (17). On the other hand, an important effect of strength training might be to prevent falling accidents. However, there is limited evidence that falling accidents become less common after strength training, but it has been shown that risk factors for falls, such as muscle strength, walking ability and balance, are affected in a positive direction (17, 41).

There is no clear-cut evidence that strength training increases flexibility, but rather it can decrease with strength training. A comprehensive programme is therefore recommended to include flexibility training as well as aerobic training and strength training (4).

8. Joint pain/back pain

The wear and breakdown of cartilage in the knees leads to pronounced pain and disability. Strength training has been shown to decrease pain and improve function (17, 44–46). After cardiovascular disease, chronic pain in the lumbar region is one of our largest health problems. It has been shown that a specific training programme for the lumbar region, comprising only one set of 8–12 repetitions once per week, can provide reduced pain and increased strength and flexibility (47). In this context, it should, however, be mentioned that many other types of strength training, as well as other types of exercise, are effective for the treatment of chronic lower back pain (48). Strength training was applied as early as the 19th century and early 20th century for rehabilitative purposes, but then "fell into oblivion" for nearly 100 years, a period during which treatment methods such as ultrasound, electric stimulation and massage have been dominant (47).

9. Mental health

Both aerobic training and strength training can alleviate the symptoms of depression and anxiety. Ten weeks of strength training among depressed elderly persons proved to significantly reduce all measures of depression (49). However, it has not been shown that training can prevent the onset of these symptoms (50). Interesting finds include that the length of an individual exercise session appears to be of significance to the effect on the state of mind. According to these studies, the training session should exceed 20 minutes and more optimally amount to 30–40 minutes (50).

Table 2. Effects of strength training.

1.	Muscle strength	↑↑↑
	Muscle mass	↑↑
2.	Maximal oxygen uptake	↔ ↑
	Endurance	↑
3.	Basal metabolic rate	↑
	Fat mass	↓
4.	Insulin sensitivity	↑
5.	Blood pressure	↓ ↔
6.	Lipoproteins	↓ ↔
7.	Bone density	↑ ↔
	Fall risk	↓
	Balance	↑
	Flexibility	↔ ↓
8.	Joint pain	↓
	Back pain	↓
9.	Mental health	↑

Modified from Hurley and Roth (17) and Pollock and Evans (12).
↑↑↑ = very large increase, ↑↑ = large increase, ↑ = increase, ↓ = decrease, ↔ small or no change or varying findings.

Is strength training dangerous?

If strength training is done as per the recommendations, the collective assessment is that strength training is a least as safe as aerobic training if not safer (9, 51–53), but like other physical training, there is some risk, although very little, of cardiovascular and musculoskeletal complications in strength training.

In a study of elderly men and women, only two minor musculoskeletal injuries were found per 1,000 hours of training, and in most cases, training could be resumed after a period of rest (54).

Very few cardiovascular complications have been reported in connection with strength training among both the young and the old, including individuals with cardiovascular disease, for example. Among 57 heart attack patients, who trained both strength and aerobic fitness for 12 weeks, only one patient had an uncomplicated imbalance of the heart rhythm during a strength training session, while a total of 45 patients had chest pain or an ECG change indicating a lack of oxygen in the heart or a rhythm disturbance during the training or tests of aerobic fitness (53).

The fear of strength training that sometimes occurs is based in the hemodynamic response that has been shown in some forms of strength training. For example, studies show that young men who carry out repeated concentric and eccentric contractions with both legs to maximum fatigue with a load of 90 per cent of 1 RM can reach blood pressures in the magnitude of 300–400 mm Hg (38, 55). Research subjects in these studies were permitted to hold their breath (so-called Valsalva's manoeuvre) in connection with the lifts. However, later studies show that the hemodynamic response is more moderate, approximately as in aerobic exercise, if abdominal pressure is avoided (56–59). To reduce the risk of sharp increases in blood pressure, regular breathing is recommended in connection with strength training and to exhale when the exertion is at its greatest (the lift phase and/or contraction phase) and to inhale when the exertion is less (return and/or the extension phase) (9, 52). For patients with increased risk of cardiovascular complications, such as early after a heart attack, it is also recommended to not exceed 15–16 (hard) on Borg's RPE scale (60).

Another discussed risk is that strength training, through major blood pressure increases, could lead to heart enlargement of a concentric type, but most studies indicate that this concern is exaggerated. Among body builders who abuse anabolic steroids, however, heart enlargement and degraded diastolic heart function have been found (61).

Contraindications to strength training

Absolute:

- Unstable coronary-artery disease
- Uncompensated congestive heart failure
- Uncontrolled cardiac arrhythmia
- Pulmonary hypertension (severe, > 55 mm Hg)
- Aortic stenosis (serious)
- Acute myocarditis, endocarditis or pericarditis
- Uncontrolled high blood pressure (> 180/110 mm Hg)
- Aorta dissection
- Marfan syndrome
- High intensity strength training (80–100% of 1 RM) among people with serious kidney failure due to diabetes (diabetes nephropathy)
- Diabetes retinopathy

Relative contraindications (consult physician):

- High risk of cardiovascular disease
- Uncontrolled diabetes
- Uncontrolled high blood pressure (> 160/> 110 mm Hg)
- Severely impaired aerobic fitness (< 4 MET)
- Limitations in muscles or skeleton
- Those with a pacemaker or defibrillator

Williams et al (8).

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