EFFECTIVE WEIGHT REDUCTION IN PATIENTS WITH METABOLIC SYNDROME BY AN INDIVIDUAL SPORT THERAPEUTIC PROGRAM - AN EMPIRIC ANALYSIS

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Abstract

Objective: The most successful strategies to treat metabolic syndrome combine changes of nutrition / lifestyle with activity or sports. The latter includes aerobic endurance training only in most studies. We investigated the efficacy of a highly individualized program which also includes strength training to increase the highly metabolic active muscular tissue.

Methods: Prospective study with 48 probands (17 males, 31 females, mean body weight 104.3 kg (+/-23.64), mean BMI of 36.3 (+/-6.76)). All were trained in nutrition and all got an individualized sport program which focused both, aerobic endurance and strength. Observation period was three months. Primary outcome measurement was reduction of body weight and BMI, secondary parameters were abdominal circumference, body fat, total cholesterol, high density lipoproteins (HDL), low density lipoproteins (LDL), triglycerides, and uric acid.

Results: The reduction of body weight and BMI were highly significant ($P < 0.001$) as it was for abdominal circumference ($P < 0.001$) and body fat mass ($P < 0.001$). Mean HDL and LDL showed tendencies to normal values, cholesterol decrease was (marginal) significant ($P = 0.052$). Triglycerides and uric acid remained constant during the observation period.

Conclusion: The program proved to be highly effective, although a direct comparison to others is difficult for several reasons. These and the limitations of the study are discussed in detail.

Key words: metabolic syndrome, nutrition, aerobic training, strength training, body fat

Introduction

Overweight, obesity and metabolic syndrome are typical problems in industrial countries, but also in transitional countries the proportion of obese people in the population is increasing significantly. The World Health Organization (WHO) estimated in 2005, that about 1.6 billion persons older than 15 years worldwide were overweight with a significant tendency of further increase [1]. In Germany 65% of the men and 55% of the women are overweight (Body Mass Index (BMI) higher than 25 kg/m²). There is international consensus, that overweight causes several severe diseases like diabetes, disturbances of carbohydrate and fat metabolism, hypertension, osteoporosis, and others. But several studies also report correlations with malignant diseases like carcinoma of the oesophagus, mamma, rectum, pancreas, kidneys, cervix uteri, sigmoid and colon. But there are even more consequences like social isolation which increases with BMI, an increased fatigueability, displeasedness with the own body, sense of shame and depressive disorders [2]. The consequences on the national health systems are enormous: it was estimated that 3-6% of the annual costs are caused by adipositas and adipositas-related diseases [3]. The problem is not

exclusively caused by hypercaloric nutrition, but also by a deficiency of activity.

There are many different studies about overweight, obesity or metabolic syndrome and sport, but nearly all of them focus on aerobic training only [4]. Since such strategies ignore that an increase of muscular mass improves the metabolic activity and therefore should optimize weight loss, we investigated a programme which included nutrition, aerobic training and strength training.

Methods

Participants

A retrospective pilot study of patients who completed the same program than the study group later in the prospective design was performed to estimate the number of probands which are necessary to prove the hypotheses (32 persons (17 females), mean age 51.7 years (32-68)). The calculation resulted in a number of at least 10 for the prospective study.

Inclusion criteria for the prospective study were a BMI of at least 27 kg/m² or a BMI of at least 25 kg/m² in combination with an adipositas related disease. Since there is not yet a generally accepted definition

of metabolic syndrome and diabetes, hypertension, dyslipidemia, and insulin resistance must not all be present in contrast to overweight which is a must, we decided to use the definition “overweight plus at least one related disease” or extreme overweight for the study presented here. Clinical checkups proved that all of the latter patients showed dyslipidemia. Exclusion criteria were orthopaedic or internal diseases which did not allow the individual to participate in the training program (e.g. hypertension with non-sufficient therapy, defined as blood pressure >150/100 mmHg), age under 18 years, and mental inability to understand the study and to give an accurate written consent.

Primary outcome measures were the reduction of body weight and reduction of BMI. Secondary parameters were the abdominal circumference [cm], body fat [%], total cholesterol, high density lipoproteins (HDL), low density lipoproteins (LDL), triglycerides, and uric acid. Blood samples were taken at the beginning and at the end of the study. All participants were advised not to eat or to drink anything except tea or mineral water for at least four hours before the blood samples were taken. Body weight was measured with a calibrated precision scales (Body-Check KFW 4019, Fa. Korona, Art. No. 801 4019, accuracy of measurement 100 gr.). Body fat was measured by impedance with the Body Fat Monitor BF 306 (Fa. Omron, Art. No. 086 000 000, accuracy of measurement 4.1% of body fat mass). Serum glucose and HbA1c were also monitored, but since it was not possible to get fasting serum probes (early morning test) from all of the participants we used glucose as an indicator whether activity or safe sports is possible with regard to the actual situation of the individual's glucose metabolism.

A total of 48 probands entered the study and all of them completed the protocol described in detail below, which lasted for a period of three months. 17 of the participants were males, 31 females. Mean age was 52.1 years (26-71, median 52.5).

The study consisted of two parts which followed immediately on each other: i. medical pre-check, fitness test, and dietary training, and ii. the “training-diet phase”. The participants did not get a systematically dietary training before the first part of the study. All participants got detailed training and information in optimal nutrition and changes of lifestyle necessary to fight metabolic syndrome in standardized lessons at the beginning of the study. This and the coaching of the probands during the study was performed by a team consisting of a nutritionist, a diabetologist, a physician specialized in nutrition, and an educationalist. Together with the individuals the team analysed the nutrition of the participants in detail and an individual nutrition concept was then developed according to the recommendations of the German Society for

Nutrition. For this process the software of the Society was used (“DGHE Ernährungssoftware DGE-PC professional Version 3.0”). All probands had to take care for detailed documentation of their nutrition, body weight and participation in the sports program. Coaching included a check of the dietary records at the beginning of each training session and – where applicable – a discussion of the consequences. Previous pilot studies had shown that this procedure increases the compliance of the patients significantly.

The individualized sports program used group dynamics to get the feeling of pleasure across to the obese patients since such persons are known to suffer from compunction because of their weight and that they are uninhibited in a group. The training was performed three times per week (every second day except Sunday). Sports consisted of endurance and of strength training (2/3 to 1/3 of the time). Endurance training was performed in steady state modus for 30 (-60) min. in 1 (-2) units with a pause of 30 min., when 2 units had to be done. The workload was strictly within aerobic range at 40 (-70)% of the individual maximal workload. This was tested by the IPN Test according to Lagerstrom et al. [5,6]. This test evaluates the aerobic workload in W/kg body weight at the Mader threshold [7-10]. For higher accuracy the test does not follow the Hollmann scheme of ergometry [8] since it increases the workload at the cycle ergometer for 25 Watts every 2 minutes. When diabetic patients, patients with known coronary heart disease or intake of betablockers were tested this was done in the presence of a physician. Heart rate during training (HRT) was evaluated as follows: $HRT = HR_{rest} + [(220 - age [yr]) - HR_{rest}] \cdot X$ with X = actual (planned) workload as % of maximum workload. To control workload during training by heart rate (HR) is generally accepted as safe and effective since decades and widely used in any kind of endurance sports (e.g. [8,11]). But it should be taken into account that there are different effective loads when different machines are used (e.g. cycling ergometer, treadmill and stepper). For our study apparatuses of Proxomed were used. These systems are computer assisted and automatically reduce workload if a proband exceeds his or hers individual threshold.

Strength training was performed as extensive interval strength endurance training (3x 30 repetitions without load relieving and 1 min. pause between the three sets). For back muscle training the so-called “shoulder fixator” (Fig 1), the rudder traction machine (Fig 2), and Latissimus-dorsi-system (Fig 3) were used. For pectoral muscle training the pectoral system as shown in Fig 4 was used. Shoulder muscles were trained with dumb-bells: with the elbow flexed at 90° the arms had to be lifted laterally until the elbows were at the shoulder's level. Arms were trained with biceps

Figure 1. Shoulder fixator for back muscle training

Figure 2. Rudder traction machine for back muscle training

Figure 3. Latissimus-dorsi-system for back muscle training

Figure 4. Pectoral muscle training

Figure 5. Leg extensor system

Figure 6. Training System for the adductors and abductors of the hip

Figure 7. Training of the leg's extensors

curls and triceps extension and the legs with the leg extensor (Fig 5). The systems for the adductors and abductors of the hip and those for the leg's flexors are shown in Fig 6 and Fig 7, respectively.

Training was not allowed before detailed information was given about correct body position, how to move and to breathe. The probands were advised to avoid forced respiration during expulsion strictly. Any training was surveyed by trainers and a sport physician. Every six weeks the loads of the strength training was regularly adjusted to the actual training status to keep the load at 40-60% of the maximum force as it was done for the endurance training.

Statistical analysis

Because some data did not follow normal distribution non-parametric tests were used for statistics (Wilcoxon-signed-rank-Test). $P < 0.05$ was defined as significant. The study protocol was completely approved by the ethical committee of the University of Salzburg / Austria (19.5.2008).

Results

Primary outcome measures

The collective ($n=48$, 17 males, 31 females) entered the study with a mean body weight of 104.3 kg (± 23.64) and a mean BMI of 36.3 (± 6.76). At the end of the 3-months period of the study mean body weight had reduced to 99.6 kg (± 22.74) with females showing more absolute and relative weight reduction than males (-5 kg (99 to 94 kg) vs. -4 kg (112 to 108 kg)). The mean reduction of 4.7 kg is highly significant ($P < 0.001$). Mean BMI reduced by 2.03 to 34.3 (± 6.44), which is also highly significant ($P < 0.001$).

Secondary outcome measures

Mean abdominal circumference was 118.6 cm (± 15.57) at the beginning of the program and reduced to 110.9 cm (± 14.96) at the end ($P < 0.001$). Body fat mass reduced from 40.4% (± 5.84) to 38.3 (± 6.46), which is also highly significant ($P < 0.001$). Mean HDL was 50.4 mg/dl (± 16.85) first and 51.4 mg/dl (± 13.85) at the

end. This increase is not significant ($P=0.651$), but reflects a clear tendency to increase HDL by the program. Mean LDL started with 125.5 mg/dl (± 42.22) and showed 121.7 mg/dl at the end, which also was not significant ($P=0.151$). Mean total cholesterol decreased from 229.3 mg/dl (± 99.19) to 208.4 mg/dl (± 46.01), which is (marginal) significant ($P=0.052$). Mean triglyceride levels were 308.5 mg/dl at the beginning (± 793.49) and 195.1 mg/dl (± 103.26) at the end. The enormous standard deviation is mainly influenced by one subject. Without this person the respective values were 193.7 mg/dl (± 100.12) and 190.3 (± 101.64). Neither with nor without this outlier the difference was not significant ($P=0.488$, respectively 0.646). Uric acid did not change. It started with a mean value of 6.0 mg/dl (± 1.49) and 5.8 mg/dl (± 1.37) at the end of the study ($P=0.96$).

Discussion

We investigated the effect of a combined program which included nutrition / lifestyle parameters, aerobic endurance training, and strength training on several parameters of metabolic syndrome. The study was part of a complex project. Here we focus on body weight and lipid profile while data about glucose metabolism and diabetes are published elsewhere [12]. In the study presented here all primary and most of the secondary outcome measurements showed significant improvement.

In international scientific literature obesity is rated according to the criteria given by the WHO (Table 1). The weight reduction of our probands corresponds to a mean reduction of the WHO obesity grade from Class II to I. 9 participants could reduce their body weight in such an extend, that they fulfilled the criteria of WHO class "overweight" and not "obesity" anymore.

Table 1. WHO criteria for obesity [1]

WHO class	BMI [kg/m^2]
Underweight	< 18.5
Normal weight	18.5-24.9
Overweight	25-29.9
Obesity Grade I	30-34.9
Grade II	35-39.9
Grade III	40+

Of the secondary parameters the abdominal circumference and its significant decrease is of special interest, since it is accepted as an independent and important risk factor for several cardiocirculatory diseases [13-26], but also for other diseases like female cancer [15,27], diabetes mellitus and related problems like insulin resistance [15,18,20,28-30], fatty liver [31], gallstone disease [32], colorectal adenoma or other neoplasm [29,33], premature death [15], Barret's oesophagus

[34], erosive oesophagitis [35-37], hernia [38], asthma [39], urinary incontinence [40], prostatic hyperplasia or cancer [41,42], a higher postoperative risk [43,44], obstructive sleep apnea syndrome [45], or metabolic risk factors in general [46,47]. Whether BMI or abdominal circumference is the more appropriate predictive factor, is still a matter of discussion (e.g. [47-50]), but it is well proven that the latter has a high precision, a low bias over a wide range of ethnic groups [51], although some authors report different results [52-55].

The body fat decreased significantly although there was an increase in muscular mass by the strength training. This indicates an even higher effect of the program towards a benefit for the whole body: Since muscular tissue has a higher specific weight than fat, the reduction of body fat during the period of the study is even more pronounced than the pure analysis of the body weight or BMI would indicate. Some of the metabolic inactive fat has been replaced by metabolic active muscular tissue. As expected, the transport proteins of fat (HDL, LDL) shifted during the training towards a lower atherogenic index. Only uric acid, which should be taken into account because obesity is a risk factor of hyperuricemia and the latter is an independent risk factor for cardiovascular mortality [56], did not change.

In medical literature there are three groups of strategies for weight management in obese patients: diet only, sport only, and combined dietary sport programs. In a meta-analysis of the literature of 25 years Miller et al. compared 493 studies, 293 of them with a pure dietary strategy, 90 with sport strategy, and 134 with a combined strategy [4]. With a mean sample size of 33 (+/-6) weight loss was 2-55kg over a period of 2-90 weeks. The frequency of sports was 2-7x/week for 14-120 minutes. Although the settings differed much, programs which combined dietary aspects with sports were superior to others [4]. With such combined strategies up to 77% of the patients could stabilize the reduced weight for at least one year compared to dietary groups with 56% and pure sport groups with 53%. This was different in the study published by Jakicic et al., where there was no significant difference between the different subcollectives [57]. But there was another interesting result: obviously it is more important that obese patients perform sports than the "dosage" of sports, since there was no significant between those who performed a program with a high training volume vs. those with a lower one. But the author discusses this result very careful since the enormous number of different sports and therapeutic strategies makes it simply impossible to extract something which could be called "perfect dosage of training" from the different protocols. But others confirmed the observation that sports as principle change in life style is more important than "how much sports" [58].

However, most authors report less weight reduction after a combined sport-dietary program than some of the studies included in the meta-analysis referenced above. Most results of combined programs are within the range of the data from Ross et al. [59], who reported -16% body weight (e.g. [60]). They also proved, that this loss is mainly caused by a loss of abdominal fat. Like others, their patients improved their glucose tolerance and insulin resistance. Hagan et al. published similar results [61]. The effect might last much longer as the activity itself, since the metabolic rate at rest is higher in active persons compared to sedentary ones, probably by a higher activity of the sympathetic system via beta receptors [62].

Donnelly et al. pointed out, that sex-related factors may interfere with the study's results, since female overweight college students could stabilize their weight when they performed sports while male students reduced it [63]. Others demonstrated that a long-lasting strategy with activity included is extremely important to stabilize the reduced body weight over a longer period [60, 64-67], although this has to face various psychological barriers [68]. The necessity of a long-lasting strategy may be a consequence of the effect that previously obese persons show a reduced fat oxidation capacity compared to thin persons [69,70]. This causes susceptibility to a positive fat balance while activity increases fat oxidation.

The effect on fat metabolism was focused in many studies. Like ours, most of them showed an amelioration of the atherogenic index, an increase of HDL and decrease of LDL, triglycerides, and plasma leptin [71-73].

The amount of sport activity was investigated in several studies. Jakicic et al. showed in two different studies, that 200 to 300 minutes per week causes a significant and long-lasting effect in obese women [57,74]. Others reported similar results with 60-90 min. daily, corresponding to 2500 to 2800 kcal per week [75,76] and this was also included in the Dietary Guidelines 2005 [77].

Studies which include fat-free muscle mass as parameter are rare, which is surprising since muscles are metabolically highly active tissue. Garrow et al. reported, that strength training did not induce a significant loss of body weight, but an increase of fat-free muscle mass [78]. Waddell et al. reported similar results for an observation period of 40 weeks [79]. In contrast to these studies all of our subjects showed booth, loss of total weight loss (respective body mass) and an increase of muscle mass. But a direct comparison is difficult as the protocols were different. This is the same problem when studies which combine sport and change in life-style or nutrition are compared. The differences between the activities and / or changes of nutrition vary too much and therefore recommen-

dations for the “perfect strategy” – if there is such a strategy – cannot be given.

Some factors may have limited our study and should be taken into account: The observation period was limited to three months. This may have facilitated to motivate the participants, but it also inhibits to give any data about long lasting effects. Acute diseases may have interfered with the study, but no such a disease was reported by the participants and since they joined the sport sessions regularly they were not asked for by the trainer or physician. Since some of our participants suffered from extreme obesity at the beginning, a very low level of activity – in some cases 30-40 Watts only – was possible. This low level of activity may have decreased the mean values of the total collective. The intake of calories was not recorded in detail. It may have happened that some participants have felt hungrier after sports and therefore they may have increased their daily calories.

Summarized, the combination of changes in nutrition, aerobic sports, and strength training improves body weight, abdominal circumference, fat metabolism and atherosclerotic index. A special advantage is the increase of metabolic active muscle mass. Another advantage is the individualisation of the training which was an important factor which increased the probands' compliance.

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Declaration of interest

The authors reports no conflicts of interest.

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