Wenzel H, Unger E. Influence of a six-month strengthening programme on HbA1c, cholesterol and triglycerides in type II diabetics: A pilot study (Original research). SEEJPH 2016, posted: 23 March 2016. DOI 10.4119/UNIBI/SEEJPH-2016-96

ORIGINAL RESEARCH

Influence of a six-month strengthening programme on HbA1c, cholesterol and triglycerides in type II diabetics: A pilot study

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Abstract

Aim: To assess the feasibility and effectiveness of resistance training on glycaemic control in adults with type 2 diabetes, the additional risk factors including low physical activity, measured by HbA1c, body weight, cholesterol and triglycerides.

Methods: We conducted a pilot study as a pre-and-post study with no control group. Participants had to meet the following inclusion criteria: type 2 diabetic person, 45-75 years old, duration of diabetes <10 years, no experience with resistance training within the last ten years, willingness to attend regularly the training sessions (two training units per week, with 45 minutes of duration each). Furthermore, a certificate from the treating physician (diabetologist) was requested, testifying that there were no medical reasons against participation. Patients with severe accompanying diseases, high blood pressure, heart failure (NYHA III), or retinopathy were excluded. Eighteen persons (10 men, 8 women), aged 46-71 years could be included. Due to dropouts, the pre-post-evaluation was based on 13 individuals only. Mean age of this group (6 men, 7 women) was 63.6±5.5 years. Mean body mass index at the beginning was 29.8±4.9. Mean HbA1c was 7.5%±0.6%; the triglycerides were in the range between 134 mg/dl and 335 mg/dl with an average value of 195.8±50.9 mg/dl. Cholesterol level was between 149 mg/dl and 262 mg/dl, which corresponded to an average of 206.6±34.8 mg/dl. The training took place in a fitness centre under the supervision of a certified sports scientist between April 2010 and October 2010 for 28 weeks. During the training period, the patients were asked to report whether they changed their level of general physical activity during this period, as a potential confounder. Possible treatment adaptations had to be recorded.

Results: At the end of the study, the average HbA1c dropped from 7.5%±0.6% to 7.1%±0.8%. Mean cholesterol level dropped from 206.6±34.8 mg/dl to 191.3± 30.85 mg/dl. Mean triglycerides were lowered from 195.8±50.9 mg/dl to 144±30 mg/dl. These changes were all statistically significant ($P<0.05$). The dose-response curve was not significant, probably due to the small number of participants.

Conclusions: There is now suggestive evidence supporting the use of resistance training for improving glycaemic control and insulin sensitivity in type 2 diabetes. However, this has not been perceived clearly enough to date. It is also not in the focus of economic evaluations of diabetes preventing strategies. Activating diabetic patients to perform resistance training is an effective and efficient way to reduce the burden of diabetes and, even more, to prevent this disease.

Keywords: cholesterol, HbA1c, pilot study, triglycerides, type II diabetes.

Conflicts of interest: None.

Introduction

Diabetes affects patients and their families, health insurance and society. Diabetes lowers average life expectancy of the patient increasing cardiovascular disease risk two to four fold, and is the leading cause of kidney failure, lower limb amputations, and adult-onset blindness. The disease puts a significant economic burden on society and healthcare programmes (1) and leads to considerable stagnation of national economies. The costs of caring for patients that are suffering the consequence of complications are four times higher than those without complications (2). As the International Diabetes Federation emphasizes, complications due to diabetes are a major cause of disability, reduced quality of life and death (3).

Just over 8.3% of the global population between 20 and 79 years has diabetes, which was about 415 million in 2015; by 2040, this figure will rise to 642 million (4). The number of people with diabetes in 2013 in Europe was estimated at 56.3 million, which is 8.5% of the adult population. Turkey has the highest prevalence (14.8%) and the Russian Federation has the greatest number of people with diabetes (10.9 million). By contrast, Azerbaijan has an estimated prevalence of diabetes of just 2.4%. After Turkey, the countries with the highest prevalence are Montenegro (10.1%), Macedonia (10.0%), Serbia (9.9%), and Bosnia and Herzegovina (9.7%) (3).

Diabetes imposes a large economic burden on individuals and families, national health systems, and countries. According to a report of the International Diabetes Federation (3), health spending on diabetes accounted for 10.8% of total health expenditure worldwide in 2013. Most of the money has to be spent for treating the complications. It is not diabetes or its management that causes most costs; rather, it is the consequences of the complications (4,5).

At present, type 1 diabetes cannot be prevented. The environmental triggers that are thought to generate the process that results in the destruction of the body's insulin-producing cells are still under investigation. But, there is significant evidence that lifestyle changes (achieving a healthy body weight and moderate physical activity) can help prevent the development of type 2 diabetes (6). Obesity, particularly abdominal obesity, is linked to the development of type 2 diabetes. Weight loss improves insulin resistance and reduces hypertension. People who are overweight or obese should therefore be encouraged to achieve and maintain a healthy body weight (6,7). A reduced capability of insulin to boost muscle blood flow is typical for insulin-resistant obese individuals and individuals with type 2 diabetes. Exercise training, however, has been found to help improve this problem, and substantially improve the control of insulin over blood glucose (8,9).

Implementing inexpensive, easy-to-use interventions can reduce the huge economic burden of diabetes. Many of these interventions are cost-effective and/or cost saving, even in developing countries. Vijgen et al. (10) provide a detailed overview on various approaches in primary, secondary and tertiary prevention.

Prospective studies and clinical trials have shown that moderate to high levels of physical activity and an increase in physical activity levels can prevent type 2 diabetes (11), or at least - after onset - slow down progression (12). Consequently, diabetologists and others recommend physical activity (13-15). Interestingly, the plea for physical activities in the treatment of persons with diabetes is not quite new. The importance of physical activity was already recognised at the beginning of the 20th century. Allen (16, p. 495) very early became aware of the possible impact of physical activity on the glucose metabolism. Recent research shows the favourable impact of resistance training and/or aerobic training (17-22). There are also studies that show how type 2 diabetes can cause bone dysfunction and how resistance training positively impacts bone functioning (23).

In this context the purpose of this pilot study was to determine the feasibility and effectiveness of resistance training on glycaemic control in adults with type 2 diabetes, the additional risk factors including low physical activity, measured by HbA1c, body weight, cholesterol and triglycerides.

Methods

We conducted a pilot study as a pre-and-post study with no control group. Four diabetologists/internists were asked to name eligible participants from their patients. The participants had to meet the following inclusion criteria: type 2 diabetic person (T2D), 45-75 years old, duration of diabetes less than 10 years, no experience with resistance training within the last ten years, willingness to attend regularly the training sessions (two training units per week, with 45 minutes of duration each). Furthermore, a certificate from the treating physician (diabetologist) was requested, testifying that there was no medical reason against participation. Patients with severe accompanying diseases, high blood pressure, heart failure (NYHA III), or retinopathy were excluded.

Eighteen persons (10 men, 8 women), in the age between 46 and 71 years, could be included. Due to dropouts, the pre-and-post evaluation was based on 13 persons, only. The average age of this group (6 men, 7 women) was 63.6 (SD 5.5) years. Mean body mass index (BMI) at the beginning was 29.8±4.9; the range was between 22.5 and 41.4. Mean HbA1c level was 7.5%±0.6%, ranging from 6.2% to 8.6%; the triglycerides were in the range between 134 mg/dl and 335 mg/dl, with an average value of 195.8±50.9 mg/dl. Cholesterol level was between 149 mg/dl and 262 mg/dl, which corresponded to an average level of 206.6±34.8 mg/dl. According to the current guidelines, this group was likely to fall into the category "high risk" (24,25).

The training took place in a fitness centre under the supervision of a certified sports scientist for 28 weeks. During the training period, the patients were asked to report whether they changed their level of general physical activity during this period, as a potential confounder. Possible treatment adaptations had to be recorded.

Intervention

The circuit programme consisted of two sessions per week. Each session lasted 45 minutes, and was executed at eight different stations. The level of difficulty and the progression were determined individually with the intention not to surpass 60% of the maximum possible intensity of an untrained person. Intensity was defined as a combination of weight moved, the number of repetitions, and the duration of the workout. Twenty repetitions are approximately 60% of maximum intensity (26, p 229); depending on the individual situation of the test, person eighteen to twenty repetitions were carried out. This graduation was set because the study population was in relatively poor health and had to be protected against overloading. The workload was increased by 2.5 kg every two weeks until the final maximum possible capacity was reached. The only exception was the leg press where, for technical reasons, the increase steps were 5 kg.

Furthermore, the exercises were planned in such a way that both agonists and antagonists were trained likewise. The training started with a warm-up exercise on a stationary bicycle ergometer for 10 minutes. The strength training was made up of the following exercises: vertical traction, shoulder press, leg press, abductor training, low row, chest press, lower back and abdominal crunch. Two cycles per machine and up to 20 repetitions were applied. The performance of the exercises was recorded with the help of a "training key" (i.e. workload), number of repetitions, speed, and extend of the movements.

We measured weight, height, HbA1c, cholesterol, and triglycerides at baseline and weight, HbA1c cholesterol, and triglycerides at the end of the intervention.

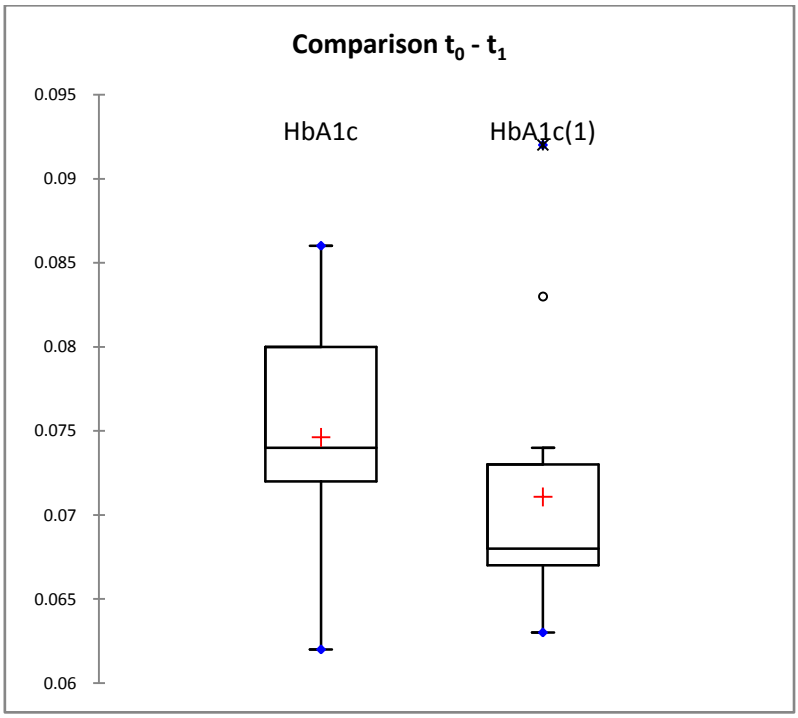
Statistical analysis

For statistical analysis, we used the Wilcoxon Matched Pairs Test. The Wilcoxon Matched Pairs Test is a nonparametric alternative to the t-test for dependent samples, which fits with the pre-and-post comparison design (i.e., repeated observations of the same person). The application does not require a Gaussian distribution of data. The variables must be measured in such a way that will allow the rank ordering of the observations (ordinal scale). We considered a p-value below 0.05 to be statistically significant (two-tailed test). Statistics were calculated with XLSTAT 2009, Version 4.07.

Results

At the end of the study, mean HbA1c dropped from 7.5%± 0.6% to 7.1%±0.8%. Figure 1 and Figure 2 provide overviews and show also the minimal and maximal values.

Figure 1. Comparison of HbA1c*

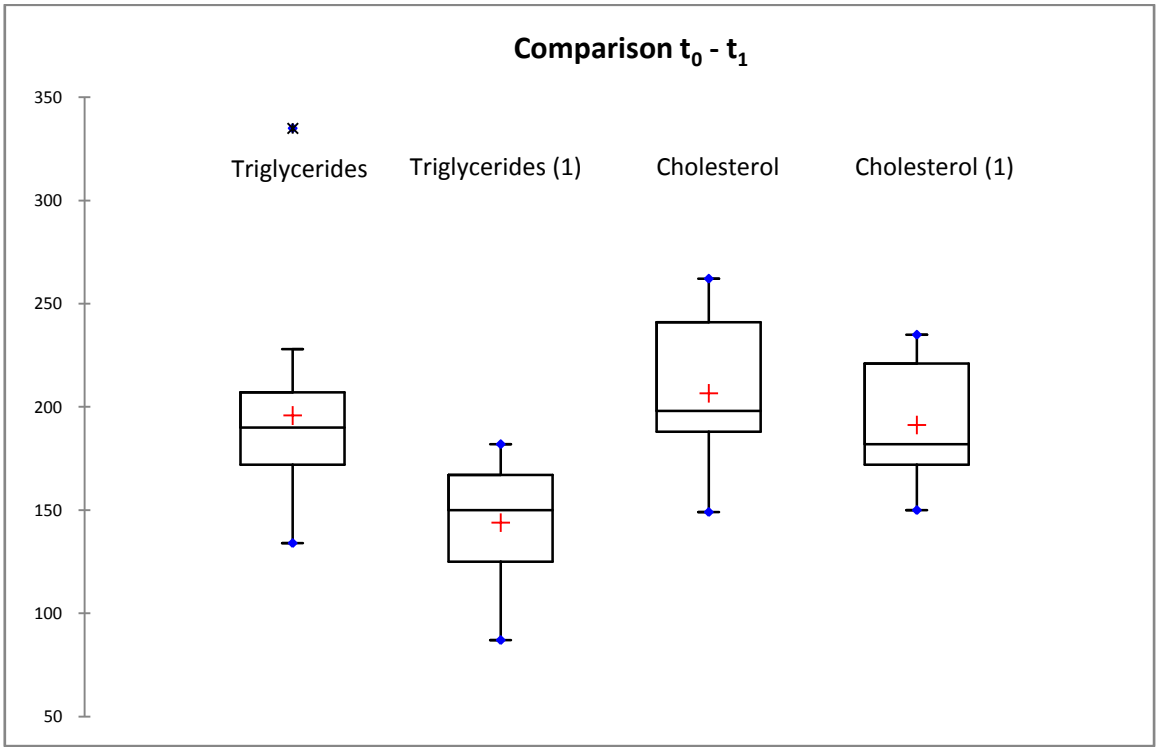


* The red cross represents the mean, the box stands for the 1st and 3rd quintile, the line in the middle is the median. The whiskers represent the minimum and maximum value, the asterisks symbolize outliers. The height of the box is the interquartile range. The differences were significant (P<0.05); n=13.

For type 2 diabetic patients the target range of HbA1c is currently set between 6.5% and 7.5%; hence, participants were close to treatment recommendations. The average cholesterol level dropped from 206.6±34.8 mg/dl to 191.3±30.85 mg/dl, ranging from 150 mg/dl to 230 mg/dl. Mean triglycerides were lowered from 195.8±50.9mg/dl to 144±30 mg/dl, with a maximum value of 182 mg/dl and a minimum of 87 mg/dl. These changes were all significant (P<0.05). Figure 1 and 2 indicate that in the case of HbA1c and total cholesterol, the interquartile range (height of the boxes) after intervention was lower than that of the initial

starting point. This means that the data are less widely spread; the minimum and maximum values are also closer to the box.

Figure 2. Comparison of triglycerides and total cholesterol*



* The red cross represents the mean, the box stands for the 1st and 3rd quintile, the line in the middle is the median. The whiskers represent the minimum and maximum value, the asterisks symbolize outliers. The height of the box is the interquartile range. The differences were significant ($P<0.05$); n=13.

Dose-response

Smidt Hansen and colleagues pointed out that there must be a dose-response relationship between physical activity and glucose metabolism (27). This means that, the higher the workload, the higher the reduction of HbA1c. We therefore compared the cumulated size of the weight that was moved during the training period by all participants with the corresponding changes in HbA1c achieved. We expected, in accordance with the principle of *"diminishing marginal returns in production curves"* (28), a rather s-shaped curve. The fitted curve of our data showed the expected incremental effect. The curve starts with a steep incline at the beginning and flattens towards the end. This is in accordance with the law of diminishing marginal returns. However, due to the small number of participants the explained variance was only 18%. Therefore, it was not possible to identify the optimum of the dose-response relationship.

Discussion

We started the training with a relatively low workload despite the recommendations how to prevent, delay, or reverse the process of losing muscle power (29-31). To increase muscle mass a training intensity of 60% to 85% of the individual maximum possible intensity is

proposed, and for forcing the muscle development Mayer et al. even advise more than 85% of maximum intensity (30). To influence sarcopenia, i.e. the age-related loss of muscle mass and function (32), this will be appropriate in a non-diabetic elderly population. To our knowledge, we have currently no training plans that are specially adapted to the needs of diabetic patients. It is also still under discussion whether it is more effective to increase the workload or the number of repetitions, mainly in the case of diabetic patients at higher ages. To determine the maximum possible intensity, the "one repetition maximum strength test [1-R]" is used mostly (30). Applying a [1-RM] strength test is somewhat critical *"because of the high stress on the musculoskeletal system and the high injury risk, especially for sportspersons involved in recreational sport"* (33, p 1). This is even more valid for our study population. Moreover, studies allow the assumption that the [1-RM] test is inappropriate for intensity control. Compared with the "multiple repetition maximum test [M-RM]", its reliability is questionable (33,34). Therefore, we applied our multiple repetition test.

Persons with diabetes are at a higher risk to develop sarcopenia. Among other things, decreased physical activity is also complemented by metabolic impairment (35); possible interactions are quite complex, and the underlying mechanism between sarcopenia and type 2 diabetes mellitus have not been clarified completely [36]. However, the Baltimore Longitudinal Study of Aging showed that hyperglycaemia is associated with lower muscle strength (37). With our restraint, we took into account that our participants were untrained for many years and that they even manifested sarcopenia in advanced stages, also in combination with obesity (39% of participants were obese). Insofar, the effectiveness of our training concept might be at the lower end of a possible dose-response relationship. On the other hand, our results are consistent with the findings of Healy and colleagues, who show that even small increments in physical activities are associated with improved metabolic control (38). Smidt Hansen and colleagues conclude that *"for persons, increasing the amount of light physical activity might be a more realistic approach rather than increasing physical activity of moderate-to-vigorous character"* (27).

According to the UKPDS and the DCCT studies, improving the HbA1c by 1% of a person with type 1 or type 2 diabetes reduces the risk of microvascular complications by 25% (39). The changes of the other risk factors are also substantial. The investigation was planned as a pilot study; nevertheless, the improvement of HbA1c found here is compatible with the outcomes of other studies (21,40). According to König et al. (40), meta-analyses show average changes of HbA1c between 0.5 percentage points and 0.6 percentage points; mean changes in our study were 0.35 percentage points (SD: 0.4). Sigal et al. report changes of 0.38 percentage points when applying resistance training alone (21). Depending on the composition of the sample under examination and the training scheme, HbA1c changes of >1 percentage points were also reported – actually, 18 percentage points in the case of a progressive resistance training over 10 weeks (41, p 5).

Cauza (42) observed a 28% reduction of cholesterol. Baseline levels of total cholesterol significantly decreased in the training group from 205.5±14.1 mg/dl to 177.5±13.3 mg/dl. In our study, the average value dropped from 206.6±9.7 mg/dl to 191.3±8.6 mg/dl. In their strength training group, the triglyceride levels were reduced from 229±25 mg/dl to 150±15 mg/dl (42). Our respective data showed a reduction from 188.8±14.12 mg/dl to 145.7±8.6 mg/dl.

Previous analyses have demonstrated that structured supervised training is more effective than unsupervised training at home (43-45). In a new meta-analysis, randomised studies with supervised training were analysed which directly compared aerobic training, resistance training and a combination of both. Combination training (CT) led to a 0.6 percentage points

improvement of HbA1c compared to resistance training. Similarly, beneficial results were found for fasting glucose, triglycerides and systolic blood pressure (43). Schwingshackel and colleagues conclude that CT might be the most effective exercise modality to improve glycaemic control and blood lipids (44). Nevertheless, they recommend cautious interpretation, due to limited information on adverse outcomes of exercise.

The outcomes of our pilot are statistically significant. However, are they significant from a medical/epidemiological viewpoint too? To assess further the health effect of the training and to evaluate the relevance of the changes, it would be worthwhile to extrapolate the changes of the risk factors to events like myocardial infarction and/or stroke. There are several risk functions available, for example the EURO Score (46), or the Framingham risk function (47) and the like. The algorithms are mostly based on blood pressure, cholesterol, LDL, HDL and triglycerides. Diabetes is coded as "yes/no" only. Therefore, as a compromise, we used the Framingham risk function to estimate in an exemplary manner the cardiovascular risk and its reduction. One of the participants in the age of 68 years with cholesterol level of 188 mg/dl, and an HbA1c of 8%, reduced the total cholesterol level to 153 mg/dl and the HbA1c level to 7.4%. If we assume that, the blood pressure (conservative) is at 140 mm Hg and HDL at 40 mg/dl (also conservative), the 10 years risk of general cardiovascular events is about 24.22%. The reduction in cholesterol reduces his risk to 19.44%. If we further could assume here that the reduction of HbA1c from 8% to 7.4% is equivalent to "no diabetes" coding, then the new 10-year risk would be 10.26%. Looking at all 13 patients, the cholesterol dropped from 206.6 mg/dl on average to 191.3 mg/dl. Based on the conservative assumptions on blood pressure and HDL, the risk would drop from 23.65% to 11.59%.

Admittedly, these calculations can only give a rough estimate of the training's health impacts, especially because the improvement of HbA1c can be modelled insufficiently only. However, the benefits for various stakeholders are obvious. The patient improves his quality of life and life expectancy, the health insurance saves money, employers have less sick days, and so on. At a first glance, it looks like a win-win situation. Unfortunately, the "investment" has to be done by the individual. It is not only expenditures, but it is also the "cost of motivation". To keep diabetic patients at it, sophisticated measures have to be introduced. They have to be based on a concept of motivation and identified barriers, which in turn possibly impede maintenance of training (48). Special attention must be given to the peculiarities and possible differences in T2D and T1D (49).

This pilot study, regardless of the small study population, is compatible with the respective literature. Nevertheless, there are some weaknesses. First of all, the pre-and-post design cannot provide "class one evidence"; controlling for confounders was difficult. Secondly, the small number of participants does not yield a high statistical power. On the other hand, there are many other studies involving small numbers too (41,50). Thirdly, more sophisticated statistical analysis is not possible due to the small number of participants. A study with more participants and the collection of all health parameters that are needed to calculate health outcomes would be required.

Conclusions

There is evidence supporting the use of resistance training for improving glycaemic control and insulin sensitivity in type 2 diabetes. However, this has not been perceived clearly enough to date. It is also not in the focus of economic evaluations of diabetes preventing strategies, i.e., lifestyle changes that were economically assed did not include resistance training. The fact that in many studies the participants had individually supervised training sessions requires larger, population-based (effectiveness) studies to ensure that these findings can be generalised. Also, further research is needed to identify the efficiency of dose-response

relationship by describing frequency and intensity of training and the sustainability of the effects, i.e. the duration of acute and chronic improvements. Activating diabetic patients to perform resistance training is an effective and efficient way to reduce the burden of diabetes, and, even more, to prevent diabetes.

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