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The effects of a 12-week combined strength and endurance training program on physical performance of patients with type 2 diabetes

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Abstract

Introduction. Physical training is considered an effective means of preventing and treating diseases of affluence such as T2DM. The key benefits of this therapy include improvements in physical performance and in metabolic processes. Aim of Study. The aim of this study was to investigate the impact of a 12-week long supervised combined strength and endurance training program on physical performance of T2DM patients with various complications. Material and Methods. The study was carried out on patients stratified into Groups (levels) 2 and 3 according to the criteria from the 2007 Danish program "Forløbsprogram for Type 2 Diabetes" (see Table 1). A total of 83 patients (29 women, 54 men) participated in the study, aged 65.5 ± 10.62 years. The subjects were offered 60 minutes of supervised group exercise, twice a week for 12 weeks. Each session consisted of a 5-min warm-up, 35-min strength exercise, and 10-min aerobic bicycling, with a load between 12 and 15 on the Borg Scale. Physical performance was measured using a 30-second sit-to-stand test (STS) and 6-minute-walk test (6MWT). Results. A significant improvement in STS was noted in Group 2 (mean = 1.6 ± 2.39; 95% CI 0.92-2.3) and in Group 3 (mean = 1.46 ± 2.14; 95% CI 0.74-2.17). Statistically significant (p <0.0001) 6MWT results were obtained in Group 2 (mean = 46.7 ± 54.08; (95% CI 30-63) and in Group 3 (mean = 46.2 ± 79.51; 95% CI 12-79). Participation in training sessions played a paramount role in improving the effectiveness of combined strength and endurance training. Conclusion. Participation in a 12-week exercise program increased physical performance in patients with type 2 diabetes, regardless of their complication status.

KEYWORDS: type 2 diabetes, risk stratification, physical function, physical training.

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What is already known on this topic?

It is a commonly held view that physical training in T2DM patients has a therapeutic effect (increases insulin sensitivity in the trained muscles and glucose uptake in muscle cells released by muscle contraction, as well as reduces diabetic complications). Several studies have also indicated a reduction in HbA1c levels as a consequence of physical training. Physical training improves patients' physical capacity (increases aerobic capacity and muscle strength) and is associated with metabolic changes (insulin resistance reduction, improved glucose tolerance). These changes are of great importance to diabetic patients.

Introduction

Diabetes mellitus is a metabolic disease. Some 382 million people worldwide, or 8.3% of adults, are estimated to suffer from diabetes. If this trend continues, by 2035 some 592 million people, or one in ten adults, will have had diabetes [1]. There are three main types of diabetes and the most common is type 2 diabetes (formerly called non-insulin-dependent or adult-onset, T2DM) which affects 90% of all diabetics [2]. The primary causes of T2DM are glucose intolerance and compensatory hyperinsulinemia, which are largely consequences of lifestyle, overnutrition and lack of physical activity, and to some extent genetic dependence [3]. Specific medication, a well-balanced diet and physical exercises are keystones in diabetes therapy [4].

In Denmark around 340,000 people have been diagnosed with diabetes. The prevalence of diabetes is 8.3% nationwide [1]. The treatment of T2DM and its complications constitutes a large expenditure for the state healthcare system as well as a significant socio-economic issue [1, 5].

The development of "Disease Management Program for T2DM" ("Forløbsprogram for Type 2 Diabetes" in Danish) was initiated in 2007 by the board of "Udvklingsforum" [6]. The "Disease Management Program for T2DM" is described as "an overall interdisciplinary, intersectoral and coordinated health care work for a given chronic disease, which ensures application of evidence-based recommendations for health professionals (…)" [7]. The original model for stratifying patients with T2DM was developed in 2006 [8, 9], and is based on risk classification criteria as shown in Table 1.

Following the risk stratification criteria, different treatment levels were provided. Patients stratified to Level 1 (Group 1) should be seen by general practitioners and followed by specialized clinics nurses. Group 2 comprised patients who either should be supervised by general practitioners, or periodically, possibly permanently, visit a diabetes clinic. Patients in Group 3 should normally attend a diabetes clinic [6].

Based on meta-analyses [11, 12, 13, 14] and systematic reviews [15, 16] about the positive effect of physical training in patients with T2DM, the Danish National Board of Health has released a supplement to "Disease Management Program for T2DM", called "Recommendations for supervised physical training of people with type 2 diabetes, COPD and cardiovascular disease. Resume" with recommendations and tests to apply in training chronically ill patients [16]. The Department of Physiotherapy of Gentofte Hospital was the first in the Danish capital region to introduce and implement supervised physical training for outpatients treated in a diabetes ambulatory.

Table 1. Risk classification criteria of patients with T2DM in Denmark [9]

	Level 1	Level 2	Level 3
Nephropathy	Norm	Microalbuminuria	Macroalbuminuria/ephropathy
Cardiovascular disease	No	Occurrence of cardiovascular problems	
Diabetic foot	No	Neuropathy symptoms or arterial insufficiency	Foot ulcers/gangrene/Charcot foot/ amputation
Retinopathy	Simplex retinopathy may occur (called non-proliferative or basic)		Macular edema or proliferative retinopathy
Blood pressure, mmHg	< 130/80		160/90 > despite attempts of optimal treatment by ½ years
Glycaemic control after the intervention	HbA1c < 7%	HbA1c 7-9%	HbA1c > 9% despite attempts of optimal treatment by ½ years
Metabolic problems associated with treatment	No	No	Tendency to serious or unexpected cases of hypoglycaemia, wide fluctuations in blood glucose

Level 1: Patients surveyed annually by a general practitioner (all level 1 criteria must be fulfilled)
Level 2: Patients not subject to level 1 or 3 crteria
Level 3: Patients requiring hospital treatment (one criterion for level 3 suffices)

Aim of Study

The aim of this study was to investigate the effect of supervised, combined strength and endurance training based on recommendations from the Danish "Disease Management Program for T2DM" on physical function in patients with T2DM stratified to Groups 2 and 3 that was implemented at the Gentofte Hospital, University of Copenhagen, Denmark.

Materials and Methods

The research was conducted on patients with T2DM stratified to Groups 2 (with special requirements – see Table 1, Level 2) and 3 (see Table 1, Level 3), referred from the diabetes ambulatory to the physiotherapy ward at Gentofte Hospital between January 2011 and the end of December 2013. A total of 83 patients (29 female, 54 male) participated in the training program. Group 2 consisted of 46 patients (15 female, 31 male), whereas Group 3 consisted of 37 patients (14 female, 23 male), aged 65.5 ± 10.60 and 68.7 ± 9.64, respectively.

Medical outpatients were offered 12 weeks of supervised group exercise twice a week of 60 minutes duration. Each session consisted of a 15 min warm-up, 35 min strength exercise, and 10 min aerobic bicycling with a load in the range of 12-15 on the Borg Scale. Physical performance was measured using a 30 s sit-to-stand test (STS) and 6 minute walk test (6MWT) before and after the training period.

Exercise program

Each training session included a 15 min cardiovascular warm-up with exercises stretching the main muscle groups (walking or jogging) followed by 35 min strength training routines performed using stack weight equipment. Each exercise at a given station was repeated 10-12 times, in three sets, followed by 40-50 seconds of rest between the series of repetitions.

Strength training intensity was calculated from one repetitive maximum (1RM) values. The starting level was 50% of 1RM, which increased individually during the training period. Endurance training of 10-15 minutes aerobic bicycling on a bicycle ergometer was individually gauged by the levels of HR, respiratory rate and sweating, corresponding to 12-15 on the Borg Scale [17, 18, 19].

Some patients replaced bicycling with additional endurance components, i.e. treadmill walking/jogging, however, maintaining the training intensity at 12-15 on the Borg Scale.

Tests

Functional sit-to-stand test (STS)

Each patient was asked to take a seated position in an armchair followed by a standing position as many times as possible within 30 seconds. The number of completed stands (up-down) was the patient's score. Patients were allowed to use armrests during the test if needed. This modification was marked in the results. During the test, patients were instructed and encouraged with standardized comments.

Six-minute walk test (6MWT)

All patients performed a standardized, self-paced 6MWT in a 30 m long corridor, at two test moments. Before the 6MWT patients were instructed to cover as much distance as possible within 6 minutes without running. Patients were allowed to stop at every moment of the test, if they needed, but were encouraged to continue walking as soon as possible. During the test, patients were instructed and encouraged with standardized comments. The distance covered after 6 minutes was truncated to the nearest meter.

Statistics

Statistical analyses were performed with STATA software (version 13.1). Continuous data were expressed as mean ± standard deviation (SD) and 95% confidence intervals (CI) for statistical tests. For all the variables, the concordance of their distributions with a normal distribution was examined. To assess the compatibility of decomposition the Shapiro-Wilk test was used. The effect of the intervention on the two outcomes was analyzed using a paired t-test for each of the two stratification groups. The level of statistical significance was set at $p < 0.05$.

Results

The results of the survey are presented in Table 2 and Figures 1-2.

Table 2 shows the results of the physical performance tests before and after the 3-month training program. For both tests the results after the exercise program were statistically significant.

A significant improvement in STS was noted for stratification Group 2 (mean = 1.6 ± 2.39; 95% CI: 0.92 – 2.3) and Group 3 (mean = 1.46 ± 2.14; 95% CI: 0.74 – 2.17). The 6 MWT improved significantly for Group 2 (mean = 46.7 m ± 54.08; 95% CI: 30 – 63) and Group 3 (mean = 46.2 m ± 79.51; 95% CI: 12 – 79).

Table 2. Physical performance results before and after a 3-month training program in respective stratification groups

Test	Group	$\bar{x} \pm SD$ Before	$\bar{x} \pm SD$ After	Delta (95% Cl)	*p* value
STS [nb]	2	11.0 ± 2.87	12.6 ± 4.06	1.6 (0.92 – 2.30)	< 0.0001
	3	9.7 ± 4.04	11.1 ± 4.10	1.4 (0.74 – 2.17)	0.0002
6MWT [m]	2	430.2 ± 127.01	476.9 ± 143.27	46.7 (30.0 – 63.0)	< 0.0001
	3	346.0 ± 140.18	392.2 ± 141.16	46.2 (12.0 – 79.0)	0.0081

$\bar{x}$ – means, SD – standard deviation, STS – sit-to-stand test (number/30 seconds), 6MWT – 6 minute walk test (meters), CI – confidence interval, $p < 0.05$ is statistically significant, $p \geq 0.05$ is non-significant

Figures 1 and 2 show the median and quartiles of test results of patients in stratification Groups 2 and 3. The median value of the STS test for patients stratified to Group 2 before the intervention was 11 (IQR 9 – 13), and after completing training program it amounted to 13 (IQR 10 – 14.7). For patients in Group 3 the median was 10 (IQR 7 – 12) and after intervention 10.5 (IQR 9 – 13) (Figure 1).

For stratification Group 2 the median value for 6MWT at start was 449.5 m (IQR 374 – 481) and upon completion – 496 m (IQR 406 – 567). For stratification Group 3 the corresponding values were: 398 m at start (IQR 278 – 420) and 423 m upon completion (IQR 291 – 496) as shown in Figure 2.

Median values for both tests conducted for both stratification groups are shown in Figures 1 and 2.

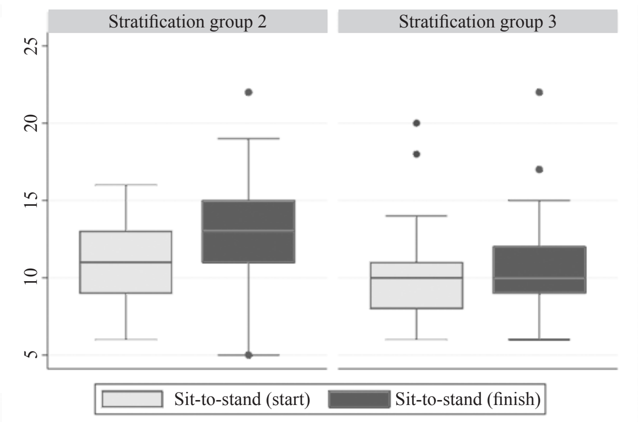

Figure 1. STS box plot for both stratification groups (center whisker – median; IQR – interquartile range; dots – outliers)

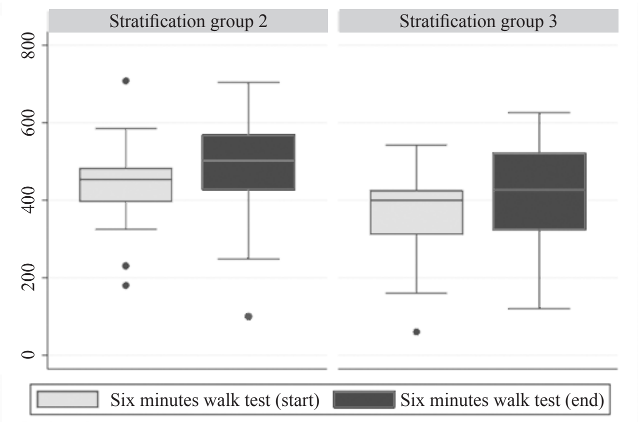

Figure 2. 6MWT box plot for both stratification groups (center whisker – median; IQR – interquartile range; dots – outliers)

Discussion

The 12-week training program implemented under the "Disease Management Program for T2DM" exhibited a significant improvement in physical performance in outpatients stratified to Groups 2 and 3.

Several studies have proven the positive effect of strength, as cited in Lambers et al. [20], and endurance [21] training in T2DM patients. Several authors have concluded that combined training had positive effects on body composition [22, 23, 24], decreased cardiovascular risk [23, 25], improved strength, muscle endurance and exercise capacity, and increased or maintained status quo in insulin sensitivity, glucose tolerance, glycaemia and HbA1c concentration [22, 23, 24, 25]. Combined training compared with endurance training seemed to be most effective in improving insulin sensitivity [26]. Moreover, Sparks et al. [27] showed that nine months of combined training significantly improved all aspects of skeletal muscle mitochondrial content and substrate oxidation as well as was most effective at reducing HbA1c levels [28] in comparison to aerobic training and resistance training, respectively.

An uncontrolled trial using combined aerobic training and resistance training in diabetic patients showed a significant increase of maximal oxygen uptake by 8-13%, and citrate synthase in muscle by 27-42% [29]. Both the American Diabetes Association [30] and the American College of Sports Medicine [31] advised a combination of both aerobic and resistive training as part of the exercise prescription for persons with T2DM.

The Danish "Disease Management Program for T2DM" suggested different training therapies for patients with a different complication status. Since this program has been implemented in the Gentofte Hospital since 2011 we have focused in the first phase on the effect of the program on physical performance in patients stratified to Groups 2 and 3. The results of the survey confirm that STS is a recommendable test for measuring strength in the lower extremities in T2DM patients [32].

The six-minute walk test (6MWT) is a simple, easy-to-perform, low tech, safe and well established self-paced assessment tool to quantify functional exercise capacity in different patients' categories [33].

Although our results indicated significant improvements in both STS and 6MWT in patients stratified to Groups 2 and 3, the results were highly differentiated as illustrated in Table 2 with large standard deviations. The World Health Organization defines compliance as the degree to which a patient correctly follows medical advice. It can apply for instance to self-directed exercises or to therapy sessions [34].

Our study demonstrated that physical performance increases with combined training in patients with T2DM. Similar results were attained by Lambers et al. [20], who showed that three-months combination training (strength + endurance) had a favorable effect on cholesterol, HDL, HbA1c and physical fitness (6MWT, STS, strength upper and lower limbs) compared with no training. Combined exercise training had significantly better effects on indices of physical condition, diabetes and cardiovascular risk compared to the control group.

Conclusion

T2DM patients stratified to Groups 2 and 3 who participated in 12 weeks of combined strength and endurance training revealed an increase in their physical performance as measured by STS and 6MWT tests regardless of complication status.

What this study adds?

This research shows that despite different diabetes related complications, sex and age, T2DM patients achieve higher levels of physical performance with supervised combined training.

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