Physical exercise is associated with improved periodontal health in type 2 diabetic patients

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Summary

Schulze A, Busse M. Physical exercise is associated with improved periodontal health in type 2 diabetic patients (CSMI) 2009, 1(9): 5-10.

Purpose
Periodontal disease may induce immune responses which may contribute to coronary atherogenesis. Diabetes is associated with increased prevalence and severity of periodontal inflammations. Exercise training may improve diabetes therapy and the overall immune status. However, we are not aware of any studies which have looked for effects of physical exercise training on periodontal inflammation in diabetes.

Methods:
Fifty type 2 diabetic subjects were examined before and after a 7.1±3.2 months` recreational training program. The training consisted of sessions twice a week, each 45 min. A self-reported oral hygiene questionnaire was completed before and after the program. All subjects underwent a clinical periodontal examination including the gingivitis index (GI), papillary bleeding index (PBI), probing pocket depth (PPD), and periodontal screening and recording (PSR). Training and diabetes parameters were also measured.

Results
Endurance capacity was improved by 70%. There were no relevant changes in weight. HbA1c was decreased from 6,6±0,9 to 6,3±0,7. Oral hygiene was unchanged. The overall PSR was significantly decreased by 19%. The GI was significantly reduced to 62%, the PBI code 3 to 42% of pre-training values. The PPD of 5mm or 6mm was significantly reduced to 64% and 38% respectively.

Conclusions:
A seven months moderate exercise training markedly improved endurance capacity and indices of periodontitis in type 2 diabetic patients. The latter effects are mainly attributed to an improvement of the systemic immune response due to exercise, but not to a major improvement of glycemic control. Another hypothesis is that an improvement of local blood flow reduces local gingival inflammation.

Key words: Diabetes, periodontal disease, inflammation, physical exercise

Introduction

Periodontal disease is characterized by local inflammation, bacteremia, a strong immune response and loss of connective tissue attachment and bone. It is speculated that a continuous long-term exposure of oral bacteremia and bacterial toxins induce immune responses which may contribute to coronary atherogenesis, and, in conjunction with other risk factors, may lead to coronary heart disease and myocardial infarction. Periodontal disease may initiate pathological changes in blood vessel walls and act as precursor of atherosclerosis. New research findings raise the possibility that periodontal disease may increase the risk of dying from a myocardial infarction almost twofold, and the risk of having a stroke almost threefold. E.g., periodontitis affects every third person over the age of 30 in the US. Severe periodontal disease is found in 5-15% of most populations [1].

Diabetes mellitus is a disease that affects millions of people worldwide (171 million in 2000). Based on 1996/97 Canadian survey data and extrapolations from American sources, the number of Canadians aged 12 and over with diabetes is estimated at 1.2 to 1.4 million (4.9% to 5.8% of the population aged 12 and over), including undiagnosed cases of diabetes. General inflammation is hypothesized to play a significant role in the development of type 2 diabetes. Numerous reports indicate a higher incidence of periodontitis in diabetic patients compared to healthy controls [2]. On the other hand it has been reported that the prevalence of diabetes in patients with periodontitis is double that seen in non-periodontitis patients [2]. Evidently a bidirectional relationship between periodontitis and diabetes exists.

The association between diabetes and periodontal disease may be due to numerous physiological phenomena common to diabetes, such as impaired resistance, vascular changes, altered oral microflora, and abnormal collagen metabolism. Furthermore diabetes is associated with chronic low-grade systemic inflammation underscored by an elevated level of specific cytokines and TNF-α [3]. IL-6, which is often seen as cause of chronic inflammation in diabetes, may rather be seen as a marker [3] or even an anti-inflammatory agent [4]. We see two possible links between exercise and periodontitis:

- Physical activity has a beneficial effect on insulin sensitivity in healthy as well as insulin resistant subjects. Long term training may potentiate the effect of exercise on insulin sensitivity through multiple adaptations in glucose transport [5]. The improved glycemic control may thus help to improve HbA1c values. Body weight may also decrease due to higher energy expenditure, decreased circulating insulin and reduced therapeutic insulin doses. Since poor glycemic control is considered a cause for periodontitis, an exercise induced improvement should theoretically improve the periodontal state.
- Another finding suggests that exercise may induce increased levels of anti-inflammatory cytokines (e.g. IL-10, IL-6), and cytokine inhibitors (e.g. IL-1 receptor antagonist, TNF-α receptor) [4,6]. Since both diseases are chronic low-grade systemic inflammations, we suggest that exercise may improve the overall immune status and thus periodontitis, independently of the effect on diabetes.

Methods

Study population and clinical data

50 well-controlled type 2 diabetic subjects aged 44 to 77 years (mean 61.2±7.4 years, weight 98.5±19kg, height 169.2±8.7cm, BMI 34.3±5.9) with periodontitis (3 or more teeth with pockets ≥ 5mm, mean: 11.1±9.7) and a minimum of 5 teeth (mean: 18.9±6.8) participated in this study. 32 of these diabetic subjects received an oral antidiabetical treatment and 18 an insulin therapy. Control of diabetes was measured by the percentage of glycated hemoglobin in the blood (mean: 6.7±0.9%). All subjects had a clinical periodontal examination to determine the gingival index (GI), papillary bleeding index (PBI), probing pocket depth (PPD), periodontal screening and recording (PSR), and number of teeth. Bridges were counted as missing teeth. The clinical dental examination was assessed by an experienced dentist. The examiner did not know that the subjects were participating in a study examining the effects of exercise on periodontal health. The examiner also was not informed about the aim and purpose of each clinical examination. These 50 diabetic patients were part of a clinical examination of 700 subjects. A Hawthorne effect can be excluded. The depth of the periodontal pocket was measured by probing the sulcus (pocket) of each tooth using a periodontal probe with a colored strip (running from 3.5 to 5.5mm) with a 0.5mm ball at the tip. The probe was inserted into the crevice until resistance was met. Readings were taken at the mesiofacial, midfacial, and distofacial areas, as well as corresponding lingual/ palatal areas (6 sites for each tooth). As a method for assessment of periodontal disease and treatment needs, the periodontal screening and recording (PSR) was used. The PSR scoring system was defined as the highest reading for each sextant according to the PSR scale and criteria: PSR code 0: health, code 1: gingivitis, code 2: calculus and gingivitis, code 3: chronic periodontitis with early or moderate attachment loss, code 4: chronic periodontitis with moderate attachment loss or a form of aggressive periodontitis. A PSR code 3 is determined when the coloured band of the probe remains partially visible (pockets = 4-5 mm). By a PSR code 4 the coloured band is not visible (pockets ≥ 5.5mm). The periodontal status was assessed by means of the PSR scoring system.

The patients received no antibiotic therapy three months prior to and during the observation period. There was no relevant change in medication and no periodontal treatment one year prior to and during the study.

Training protocol

Two training sessions per week were performed. The first session consisted of 45min endurance training (cycle-ergometer, tread mill, rowing-ergometer) and 15min of pulley exercises. The second session consisted of 45 minutes of supervised moderate swimming. The program started out with low intensity training for each form of exercise and was continuously increased according to the individuals' increasing endurance capacity. Before and after each exercise set heart rate, blood pressure, blood glucose, and work load were measured and recorded. Data at baseline and after 7.1±3.2 months of training were analysed. The cardiac load was estimated using the rate-pressure product, divided by 1000.

Questionnaire

Data were collected from a self-questionnaire, consisting of 44 questions, completed before the clinical examination. Levels of self-care were estimated using oral health behaviour items such as use of mouth rinses, frequency and time spent on tooth brushing, approximal cleaning, and dental visits. The patients oral hygiene questionnaire was used according to AM. Syrjälä [7] and Lawrence [8]. Clinical measurements and questionnaires were performed at baseline and after the training period.

Statistical analyses

The questionnaire was evaluated by determining the frequencies of the items. All data are presented as means ± SD. For the analysis of measurements, the Wilcoxon signed rank test was used to compare groups. All reported P values are two-sided.

Results

Table 1 shows BMI, Mean weight and HbA1c before and after the training period. Mean weight and BMI were unchanged over the course of the study, but mean HbA1c decreased ($p<0,004$).

Body composition and metabolic parameters

	weight	**BMI**	**HbA1c**
initial	98.4 ± 19.0	34.3 ± 5.9	6.6 ± 0.9
final	98.0 ± 18.4	34.1 ± 5.5	6.3 ± 0.7
p	n.s.	n.s.	0.004

Table 1. Weight (kg), body mass index (BMI) and glycated hemoglobin (HbA1c, %) before and after the training period.

The effects of recreational exercise training are given in Table 2. Mean training intensity was increased by 28 W ($p<0,001$). Heart rate and systolic blood pressure at rest decreased significantly ($p<0.01$, $p<0.005$). The rate-pressure product was unchanged although the endurance capacity increased by 70% after 7 months. Pre- and post-exercise blood glucose was unchanged over the course of the study.

Training effects

	baseline	**after 7 months**	**p**
endurance capacity	40.0 ± 14.0	68.0 ± 21.0	p<0.001
pre-exercise blood glucose	8.2 ± 3.0	8.2 ± 2.8	n.s.
post-exercise blood glucose	6.4 ± 2.7	6.1 ± 2,3	n.s.
pre-exercise heart rate at rest	80.1 ± 15.8	76.4 ± 13.2	p<0.01
pre-exercise blood pressure at rest	systolic: 147.6 ± 18.9 diastolic: 82.9 ± 11.4	systolic: 140.1 ± 16.4 diastolic: 80.3 ± 11.4	p<0.005 n.s.
rate-pressure product	15.7 ± 3.8	15.9 ± 3.7	n.s.

Table 2. Endurance capacity (Watt), pre- and post-exercise blood glucose (mmol x l^{-1}), pre-exercise heart rate at rest (beats x min^{-1}), pre-exercise blood pressure at rest (RR_{sys} and RR_{dia}, mmHg), and rate-pressure product (HR x RR_{sys} / 1000) before and after the training period. Please note that the rate-pressure product was similar although endurance capacity was 70% higher after training.

Table 3 summarizes the oral hygiene behaviour parameters before and after the study period. It becomes obvious that there were no relevant changes in oral hygiene regimen.

Oral hygiene behaviour parameters

	baseline	after 7 months	p
Number of teeth	19.0±7.0	19.0±7.0	n.s.
frequency of tooth-brushing per day	1.8 ± 0.5	1.9 ± 1.0	n.s.
time amount for tooth-brushing	5.6 ± 2.5	5.8 ± 2.4	n.s.
frequency of approximal cleaning	0.7 ± 0.9	0.8 ± 0.8	n.s.
frequency of mouth rinsing	0.9 ± 0.8	0.9 ± 1.0	n.s.

Table 3. Number of teeth, frequency of tooth brushing, time amount for tooth brushing per day (min), frequency of approximal cleaning and mouth rinsing per day before and after the training period.

The findings of periodontal clinical examination before and after the training period are given in Table 4. The main inflammatory (gingival index, papillary bleeding) and periodontal parameters (probing pocket depth, periodontal screening and recording) were markedly improved. The improvement of periodontal parameters ranged from 15 to 50%.

Periodontal parameters

	baseline	after 7 months	p
mean score of periodontal screening and recording (PSR)	3.1 ± 0.8	2.5 ± 1.1	0.001
percentage of bleeding sites	74.2 ± 24.1	57.7 ± 23.8	0.001
mean score of papillary bleeding index (PBI)	2.1 ± 0.5	1.9 ± 0.4	0.02
number of bleeding sites	13.8 ± 6.6	10.6 ± 6.0	0.001
number of teeth with bleeding line along gingival margin (PBI 2)	7.4 ± 4.9	6.4 ± 4.3	n.s.
number of teeth with profuse approximal bleeding (PBI 3)	2.6 ± 3.2	1.1 ± 1.5	0.001
number of sites with probing pocket depth PPD=4mm	10.4 ± 9.1	6.3 ± 6.3	0.001
PPD=5mm	11.2 ± 9.7	7.2 ± 8.5	0.001
PPD=6mm	2.6 ± 3.6	1.0 ± 1.3	0.001
gingival index (GI)	2.1 ± 0.8	1.3 ± 1.0	0.001

Table 4. Mean score of periodontal screening and recording (PSR) and papillary bleeding index (PBI), percentage of bleeding sites (%), number of sites with probing pocket depths with 4,5 and 6 mm, and gingival index (GI) before and after the training period.

Discussion

To the best of our knowledge, this is the first study which examines the effects of an exercise training program on pre-existing periodontitis in diabetic patients. Major results of general training and diabetes parameters: Endurance capacity markedly increased by about 70%, weight remained almost unchanged, HbA1c decreased significantly by 0.3%. Major results of periodontitis related parameters: There was a significant decrease of gingival bleeding and inflammation, a significant reduction of pocket depth, all inspite of no change in oral hygiene behavior.

Questionnaire

The most likely reason for the improved periodontal status after training would have been a change in oral hygiene behaviour. The results of the questionnaire rule out this possibility: almost identical answers were given after a mean of seven months. Though generally the credibility of a self-reported questionnaire may be open to doubt we feel that the obtained results are realistic for this study. The dentist advising the participants specifically instructed them to answer truthfully regardless of accepted oral hygiene standards in order to diminish any effect of social desirability. The participants were not personal patients of the advising dentist. Because of the long interval between questionnaires, the participants were unlikely to remember their initial answers. Additionally they were not informed that the questionnaire would be repeated at the end of the study. A change in oral health behaviour can therefore be ruled out as the reason for improved periodontal status.

General training effects

A seven months rehabilitative exercise training program twice a week markedly improved endurance capacity. Heart stress resulting from the combined effects of blood pressure and heart rate was markedly reduced. This is best shown by a cardiac load index (rate-pressure product x 1000^{-1}). Referred to the same workload, the rate-pressure product was only 60% of the pre-training value.

The training program had only minor effects on body weight. The increase in energy expenditure was probably compensated by the patients through an increased caloric intake.

Resting blood glucose values markedly decreased from 8.2 to 6.4mmol x l^{-1} ($p<0.001$). The lack of a major change in HbA1c values may be due to the length of the observation period, since HbA1c follows a substantial change of blood glucose with a delay of several months.

Effects on periodontal status

The most substantial outcomes, besides an improvement of endurance capacity, were related to a significant improvement of periodontal inflammation. As stated above, this improvement cannot be attributed to a change in oral hygiene practices. Which may be the underlying mechanisms causing this change?

1. <u>Exercise effect on diabetes</u>: Since periodontitis is seen as a complication of diabetes duration and intensity, the improvement of the resting blood glucose values may be one explanation for the improvement of the periodontal status.
2. <u>Exercise effect on immune status</u>: Periodontal disease is considered a chronic low grade inflammation, a local manifestation of a systemic chronic inflammation, and a complication of diabetes mellitus.

A persisting systemic immune deficit also attenuates the local immune response. According to many authors, TNF-α is recognized as a key proinflammatory cytokine. TNF-α is produced and secreted from adipocytes and plays a major role in mediating immune responses. TNF-α is also seen as a critical mediator in insulin resistance [9-11]. Therefore all factors which decrease TNF-α levels and thus its effects should enhance immune responses.

IL-6 is involved in the regulation of TNF-α levels. IL-6 exerts inhibitory effects on TNF-α production. In addition, rhIL-6 infusion inhibits the endotoxin-induced increase in circulating levels of TNF-α in healthy humans[12]. IL-6 promotes an anti-inflammatory environment by inducing the production of IL-1ra and IL-10, but also inhibits TNF-α production.[3]. Exercise may increase IL-6 depending on exercise intensity and duration [13-16]. In other words, short term increases of IL-6 may be due to exercise; a long term IL-6 increase is considered an indicator of low grade chronic inflammation.

CRP is a highly relevant indicator of risk for coronary artery disease. An increase in CRP is often related to higher TNF-α values.

According to these publications exercise should have decreased TNF-α and CRP, and the improvement in periodontitis might have been an effect of these changes.

It is a limitation of this present study that CRP, TNF-α and IL-6 were not measured. Instead, the following preliminary results were obtained from a running study on 50 type 2 diabetic patients using the same exercise program. CRP was significantly decreased after 3 months, TNF-α was even markedly increased and IL-6 remained unchanged. Assuming that these results are also valid for this present study an exercise program would improve neither TNF-α nor IL-6. Nevertheless, a relevant number of publications show an inverse relationship between CRP and periodontal inflammation[17-20]. The cause and effect relationship remains unsolved. CRP may decrease due to improved periodontal inflammation or periodontitis may improve due to improved immunological systemic conditions as an effect of exercise.

3. <u>Exercise effect on local periodontal blood flow and vascularization</u>: An increase of local gingival blood flow has been described earlier by Aars et al. [21] who showed that isometric hand grip (35% of maximum force, 2min) and the subsequent ischemia (2min) induced a brief rise in pulp blood flow and a more long-lasting rise in gingival blood flow. A beneficial effect of frequent exercise may be hypothesized since chronically inflamed periodontal tissues are a cause for stasis.

Conclusions

Regular low intensity training over 7 months markedly improves endurance and all day cardiocirculatory capacity in diabetic patients. The most substantial outcomes were related to a significant improvement of periodontal inflammation signs without any change in oral hygiene behaviour.

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