The effect of structured aerobic exercise on adherence, body mass index, hemoglobin A1c, and quality of life in type 1 and type 2 diabetes mellitus

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Introduction: Cardiovascular mortality risk is significantly increased by inactivity. Nevertheless, most patients with diabetes fail to achieve the recommended amount of weekly physical activity. Thus, strategies to establish and maintain an active lifestyle are required.

Objective: The aim of the present study was to examine the effects of a 6-month running program, Diabetes Programme Germany (DPD), on adherence, body mass index (BMI), hemoglobin A1c (HbA1c), and health-related quality of life (HRQOL).

Methods/Results: A retrospective analysis of 428 participants with type 1 (n = 177) and type 2 diabetes (n = 251) was performed. Adherence at 6 months was 75.5%. For participants who completed the program, there was a reduction in HbA1c of 0.3 ± 1.0% (P ≤ .001) and BMI of 0.7 ± 1.1 kg/m² (P ≤ .001). The greatest improvements were seen in participants with obesity (−1.3 ± 1.7 kg/m²; P ≤ .001) and with type 2 diabetes and a baseline HbA1c ≥ 7.5% (−1.4 ± 1.7%, P ≤ .001). In a post-interventional survey (response rate: n = 83), participants reported an above-average physical HRQOL. Mental HRQOL showed no significant difference from other patients with diabetes.

Conclusion: The program’s success was confirmed by a high adherence and significant reductions in BMI and HbA1c. Furthermore, a positive effect, especially on physical HRQOL, can be assumed.

Keywords: body mass index, diabetes, exercise, Glycated Hemoglobin A, patient compliance, quality of life

1 | INTRODUCTION

Diabetes mellitus has reached epidemic proportions with an increasing prevalence worldwide.1 It represents one of the most significant risk factors for micro- and macrovascular diseases.2,3 Currently, at least 7.3 million people in Germany live with diabetes mellitus.4 Twenty-one per cent of annual deaths in the German population are associated...
with diabetes. Its numerous complications significantly impact health-related quality of life. Physical quality of life is up to 15.5 per cent lower for people with diabetes than for healthy individuals.

In addition to drug therapy, lifestyle changes have always been an integral part of the treatment of diabetes mellitus. As well as improved cardiorespiratory fitness, positive effects on glycaemic control, insulin sensitivity, beta cell function, hepatic glucose metabolism, and mitochondrial function have been described in patients with type 2 diabetes. Patients with type 1 diabetes benefit from reduced insulin resistance and improved control of HbA1c as well. The effect on body weight is controversially discussed in the literature. However, there is a positive effect on cardiovascular risk factors such as arterial hypertension, hip circumference, endothelial dysfunction, and dyslipidemia. This is reflected in reduced cardiovascular and all-cause mortality. Any form of exercise has a better outcome than inactivity. Moreover, exercise has a positive impact on HRQOL.

The American Diabetes Association (ADA) recommends 150 minutes of aerobic exercise per week, divided into at least three days and with rest periods of no more than two consecutive days. In case of more intense sessions, training can be reduced to 75 minutes per week. Despite the explicit recommendation for physical activity and the obvious positive effects, samples in industrialized countries showed that most patients with diabetes are inactive (61%-64% for type 1 and 68%-72% for type 2 diabetes).

According to surveys by Leroux et al. and Brazeau et al., the main reason for patients with type 1 diabetes being inactive is the fear of complications, particularly the risk of metabolic derailments during and after physical exercise as well as a loss of control over long-term blood glucose. Other reasons given by respondents were the expenditure of time and low fitness levels. For patients with type 2 diabetes in particular, physical capacities are further limited by advanced age or increased BMI. Poor glycemic control or comorbidities, such as heart failure, also lead to a considerable reduction in performance. For all patients with diabetes, the greater the subjective physical limitation, the higher is the probability of physical inactivity.

Current research therefore deals intensively with the development of effective and sustainable strategies for promoting physical activity. Accordingly, the primary goal of the Diabetes Programme Germany was to establish a program that breaks down barriers and enables a large number of patients with diabetes to permanently integrate physical activity into their daily routines. The present application-oriented study investigates the influence of the structured running program on adherence, BMI, HbA1c, and HRQL in patients with diabetes mellitus type 1 and type 2.

2 | MATERIALS AND METHODS

2.1 | Participants

In a retrospective analysis, we examined the data of 428 participants aged 14-81 years in the DPD-structured running program. The participants had become aware of the program through advertising or directly through the general practitioner (GP) or diabetologist treating them. Inclusion criteria were type 1 or type 2 diabetes mellitus and passing a medical fitness test. For all subjects, written informed consent was obtained before the intervention. The study was approved by the Ethics Committee of the German Sport University, Cologne (059/2021).

2.2 | Study design

The subjects took part in a structured running program for 6 months between 2011 and 2014. Figure 1 shows the course of the study. Supervised endurance training twice a week prepared the participants for local running events, such as the Cologne Marathon, in which they completed partial distances. The sports program was offered at twelve different locations (Cologne, Bonn, Düsseldorf, Essen, Berlin, Minden, Meppen, Hamburg, Kiel, Frankfurt, Mainz, and Heidelberg). Following a standardized protocol, BMI and HbA1c were recorded by the treating GPs or diabetologists before and after the running program. In addition, the subjectively reported fitness (SRF) was assessed on a 5-level scale: 1 = very poor, 2 = poor, 3 = medium, 4 = good, 5 = very good.

To further evaluate each participant’s socio-demographic background, medical, and nutritional history, as well as their daily physical activity, we developed an online questionnaire containing 43 questions (and sub-questions) and sent it out post-interventionally via email in 2015. For the assessment of HRQOL, the questionnaire was supplemented by the Short Form Health Survey (SF-12). The SF-12 contains a total of 12 Likert scale questions for the evaluation of physical functioning, role limitations due to physical health problems, bodily pain, general health perceptions, vitality, role limitations due to emotional problems, mental health, and social functioning. The Physical Health Score (PCS) and the Mental Health Score (MCS) were calculated from these 8 subscales using a weighted formula. The range of
possible scores is 0 to 100, with 100 representing the best possible HRQOL.

Eighty-three participants answered the online questionnaire. As the present study only focuses on patients with type 1 or 2 diabetes, 11 respondents were excluded: seven of them had prediabetes, and four did not specify their diabetes type. A total of 72 respondents were included (Table 2), of whom 66 respondents answered the SF-12.

### 2.3 Participant training

Before starting the program, the participants were thoroughly informed in training sessions about how to adjust their medication in the context of physical activity and about strategies for avoiding glycemic imbalances. There was no fundamental change in medication. In addition, the participants received recommendations regarding adequate sports equipment for running or walking.

### 2.4 Exercise regimen

The exercise regimen was based on the ADA recommendations for physical activity valid in the year of participation. Based on the self-assessment of the participants, they were initially divided into three performance classes: Beginners with little experience in sports and the goal of walking or running 5 km or 7 km; advanced participants with previous fitness experience but without regular training who had the goal of walking or running at least 10 km; and trained people who were already exercising regularly and had the goal of running 21 km or 42 km. If necessary, the group allocations were adjusted by the coaches during the first training sessions. A supervising sports director gave each group trainer a training plan that was oriented in intensity to the experience and physical condition of the participants in that group. In addition to endurance training, this plan also included short strength and coordination units, such as squats and balance exercises. The maximum group size

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**FIGURE 1** Study flow chart
was 15 participants. To prevent glycemic imbalances and to be able to react as early as possible, participants carried out glucose checks at the beginning, during, and at the end of each training session. Before their first assignment, all coaches were trained by a diabetologist regarding disease-specific challenges in sports as well as the use of blood glucose and ketone meters, glucagon syringes, first aid kits, and fast-acting carbohydrates during the training sessions. The trainers were also required to hold at least a B trainer’s licence or equivalent qualification.

2.5 Statistical analysis

Statistical analysis was performed using IBM SPSS software version 27.0 for Mac OS. For comparison between groups (type 1 vs. type 2 diabetes), the Mann-Whitney U Test and $\chi^2$ or Fisher’s exact test were used when appropriate. To compare pre- and post-interventional data, we performed a paired t test or, if necessary, Wilcoxon test. Differences in BMI reduction were evaluated by Analysis of Covariance (ANCOVA) according to each participant’s BMI classification at baseline (Normal vs. Overweight vs. Obese), adjusted for individual and program variables. To identify predictors for $\Delta$HbA1c, we performed backward multiple linear regression using the same variables. Subsequently, the Spearman correlation coefficient was determined to calculate the correlations between $\Delta$SRF and baseline characteristics, $\Delta$HbA1c, and $\Delta$BMI. Possible influencing factors on PCS and MCS were evaluated by backward multiple regression using data obtained via the post-interventional questionnaire.

To set the post-interventional HRQOL into context, we compared our participants’ results of the SF-12 questionnaire with the sample of the German general population (n = 9579) and the subgroup of people with 2 diabetes (n = 846) studied by Schunk et al. After completion of the 6-months program, data of 211 participants were available for comparison of pre- and post-interventional BMI (see Figure 2). Overall, there was a BMI reduction of $0.7 \pm 1.1$ kg/m$^2$ (Cohen’s $d = 0.618, P < .001$). The most effective reduction was seen in patients who initially were obese (1.3 $\pm 1.7$ in obese vs. 0.6 $\pm 0.8$ in overweight vs. 0.3 $\pm 0.5$ kg/m$^2$ in normal weight, $\eta^2 = 0.109, P < .001$). In addition, reduction in HbA1c had a slight positive effect on BMI reduction ($\eta^2 = 0.043, P = .008$).

3.2 BMI reduction

After completion of the 6-months program, data of 211 participants were available for comparison of pre- and post-interventional BMI (see Figure 2). Overall, there was a BMI reduction of $0.7 \pm 1.1$ kg/m$^2$ (Cohen’s $d = 0.618, P < .001$). The most effective reduction was seen in patients who initially were obese (1.3 $\pm 1.7$ in obese vs. 0.6 $\pm 0.8$ in overweight vs. 0.3 $\pm 0.5$ kg/m$^2$ in normal weight, $\eta^2 = 0.109, P < .001$). In addition, reduction in HbA1c had a slight positive effect on BMI reduction ($\eta^2 = 0.043, P = .008$).

3.3 HbA1c reduction

In total, we were able to evaluate the long-term blood glucose values of 228 participants (Figure 3). There was a reduction in HbA1c of $0.3 \pm 1.0$% (Cohen’s $d = 0.342, P < .001$). The greatest changes were observed in participants with type 2 diabetes and an initial HbA1c ≥5.7% ($−1.4 \pm 1.7$% vs. $−0.4 \pm 0.8$% in type 1 diabetes, $P < .001$). Other factors that influenced the magnitude of HbA1c changes are shown in Table 4.

3.4 Effects on subjectively reported fitness

At the beginning of the program, most participants described their previous running experience as ‘little’ (see Table 1). Before starting the DPD, the participants’ median running frequency was ‘once a week’. After participating, median SRF improved from 3 points (corresponding to a ‘neutral’ assessment on the 5-point Likert scale) to 4 points (corresponding to a ‘rather good’ assessment) ($P < .001$). Improvements in SRF correlated with lower running frequency before the program (Spearman’s $r = −0.219, n = 166, P = .005$), lower running experience (Spearman’s $r = −0.323, n = 164, P ≤ .001$), and greater reduction in BMI during the intervention period (Spearman’s $r = −0.270, n = 159, P = .001$). There was no significant association with diabetes type ($P = .194$).
The SF-12 showed an above-average PCS for participants compared to other patients with diabetes in Germany (48.9 ± 12.1 vs. 41.2 ± 10.3; P ≤ .001). Even compared to the German general population, there was a significant difference (48.9 ± 12.1 vs. 45.7 ± 9.5; P = .007). There were no relevant differences in the MCS (50.5 ± 7.7 vs. 51.4 ± 10.2; P = .48). Neither of the parameters was significantly influenced by any of the surveyed factors.

### 4 DISCUSSION

Our aim was to investigate the effects of a structured running program on weight development, glucose metabolism, adherence, and HRQOL. The results show that patients with diabetes, especially those with an increased risk of health complications, benefit from this kind of intervention. For example, patients with a BMI ≥30 kg/m² achieved an average weight loss of 1.4 kg/m² after 6 months. Furthermore, there was a 1.4% reduction in HbA1c for patients with type 2 and a baseline HbA1c >7.5%. Overall adherence was strong, with 75.5 percent completing the program.

Owing to heterogeneity in patient cohorts and study design, a comparison of lifestyle interventions is challenging. Previous studies of exercise-based lifestyle interventions in patients with diabetes have shown different results with weight loss between 0% and 7% of BMI. The significant reduction in BMI in our study could partly be related to the large amount of exercise time per week. At an average of 228 minutes per week, the amount of exercise in our program was well above the 150 minutes per week recommended by the ADA. In addition, training with combined endurance and strength units, as conducted by the DPD, leads to greater weight reduction than interventions with mere strength training. Moreover, supervised group training has greater effects than educational guidance for self-managed exercise.

Weight reduction was dependent on BMI classification at baseline and the concurrent reduction in HbA1c.
This indicates that patients with increased health risk have the greatest potential for improvement. Both the pressure of suffering and the confrontation with their own disease, as provoked by the program, may play a decisive role. Although previous studies showed a negative effect of insulin dependence on weight loss, no association was found in our study.\textsuperscript{18,40} Furthermore, no other factors influencing weight reduction were identified in our analysis.

The reduction in HbA1c is comparable to previous interventions. A meta-analysis by Pillay et al on lifestyle interventions in patients with type 2 showed a reduction of 0.4\%.\textsuperscript{41} There, patients with a baseline HbA1c $>7.0\%$ and aged below 65 years benefited the most. In our analysis, the reduction was independent of the age of the participants.

The reduction in HbA1c was proportional to the number of kilometers completed per week. Previous interventions, however, found different results for the correlation of exercise intensity and long-term blood glucose control.\textsuperscript{11,12} A direct correlation would have an impact on the design of future interventions and should therefore be further investigated. Participants with long-standing diabetes were less successful in reducing HbA1c. This reinforced recommendations to start lifestyle interventions as early as possible.\textsuperscript{26,42}

After completion of the program, participants reported a significantly above-average physical HRQOL, not only compared to previous studies among people with diabetes but also compared to the German general population.\textsuperscript{30} HRQOL was not measured pre-interventionally. Therefore, a causal relationship between the above-average physical HRQOL and the sports intervention could not be concluded. In future studies, repeated surveys should be conducted before, during, and after the intervention. The post-interventional mental HRQOL was not significantly different from people with diabetes in the general

### Table 2: Questionnaire respondents (socio-demographic data, medical, and nutritional history)

|                         | Total group | Type 1 | Type 2 |
|-------------------------|-------------|--------|--------|
| **Socio-demographic data** |             |        |        |
| Responses, n            | 72          | 35     | 37     |
| Female                  | 47.2% (34)  | 54.3% (19) | 40.5% (15) |
| Age, y                  | 53.6 ± 10.6 (70) | 49.1 ± 10.6 (35) | 58.0 ± 8.8 (35)* |
| Education, y            | 11.8 ± 1.4 (65) | 12.0 ± 1.3 (33) | 11.5 ± 1.4 (32) |
| Migration background    | 2 (2.8%)    | 0 (0.0%) | 2 (5.4%) |
| **Family status**       |             |        |        |
| Single                  | 21 (29.2%)  | 10 (28.6%) | 11 (29.7%) |
| Married/Partnership     | 51 (70.8%)  | 25 (71.4%) | 26 (70.3%) |
| Children, n             | 1.3 ± 1.3 (72) | 1.1 ± 1.3 (35) | 1.6 ± 1.2 (37)* |
| **Medical history**     |             |        |        |
| Time since diagnosis, y | 15.3 ± 12.4 (71) | 21.6 ± 12.7 (34) | 9.6 ± 9.1 (37)* |
| All comorbidities, n    | 1.0 ± 1.4 (72) | 1.1 ± 1.5 (35) | 0.8 ± 1.3 (37) |
| Hypertension            | 17 (23.6%)  | 6 (17.1%) | 11 (29.7%) |
| Cardiovascular events   | 2 (2.8%)    | 0 (0.0%) | 2 (5.4%) |
| Hyperlipidemia          | 6 (8.3%)    | 3 (8.6%) | 3 (8.1%) |
| Neuropathy              | 3 (4.2%)    | 1 (2.9%) | 2 (5.4%) |
| Thyroid diseases        | 14 (19.4%)  | 11 (31.4%) | 3 (8.1%)* |
| Orthopedic diseases     | 2 (2.8%)    | 2 (5.7%) | 0 (0.0%) |
| Psychiatric diseases    | 3 (4.2%)    | 1 (2.9%) | 2 (5.4%) |
| Smoker                  | 5 (6.9%)    | 1 (2.9%) | 4 (10.8%) |
| Former smoker           | 29 (40.3%)  | 13 (37.1%) | 16 (43.2%) |
| **Nutrition**           |             |        |        |
| Balanced diet prior to  | 43 (59.7%)  | 21 (60.0%) | 26 (70.2%) |
| intervention            |             |        |        |
| Dietary changes during  | 27 (37.5%)  | 6 (17.1%) | 21 (56.8%)* |
| the program             |             |        |        |

Note: Data in n (%) or mean ± SD (n).

*Significantly different compared with type 1 diabetes ($P < .05$).
### Table 3 Daily physical activity

| Activity level at work                          | Total group | Type 1 | Type 2 |
|------------------------------------------------|-------------|--------|--------|
| Exclusively sedentary activity                 | 31 (54.4%)  | 17 (54.8%) | 14 (53.8%) |
| Predominantly sedentary                        | 10 (17.5%)  | 6 (19.4%)  | 4 (15.4%)  |
| Moderate exercise                              | 12 (21.2%)  | 6 (19.4%)  | 6 (23.1%)  |
| Intensive exercise                             | 4 (7.0%)     | 2 (6.5%)   | 4 (7.7%)   |

| Length of commute (km)                         | 14.3 ± 13.5 (53) | 13.5 ± 13.8 (30) | 15.5 ± 13.25 (23) |

| Coping with the commute                        |             |        |        |
|------------------------------------------------|-------------|--------|--------|
| On foot                                        | 2 (3.7%)    | 1 (3.3%) | 1 (4.2%) |
| Bicycle                                        | 8 (14.8%)   | 5 (16.7%) | 3 (12.5%) |
| Car                                            | 27 (50.0%)  | 14 (46.7%) | 13 (54.2%) |
| Public transport                               | 10 (11.1%)  | 3 (10.0%) | 3 (12.5%) |
| Several                                        | 7 (13.0%)   | 11 (28.2%) | 7 (23.3%) |
| Home office                                    | 4 (7.4%)    | 2 (6.7%) | 2 (8.3%) |

| Travel on foot/bike (leisure and work)         |             |        |        |
|------------------------------------------------|-------------|--------|--------|
| Hours per week                                 | 4.0 ± 6.4 (72) | 3.0 ± 3.0 (35) | 4.9 ± 8.4 (37) |

| Physical work                                  |             |        |        |
|------------------------------------------------|-------------|--------|--------|
| Hours per week                                 | 5.6 ± 9.3 (72) | 2.5 ± 3.1 (35) | 8.0 ± 12.1 (37) |

| Sedentary work during the week (hours per day) |             |        |        |
|------------------------------------------------|-------------|--------|--------|
| At work                                        |             |        |        |
| Mainly screen work                             | 3.8 ± 3.5 (57) | 4.5 ± 3.3 (27) | 3.2 ± 3.5 (30) |
| Other office work                              | 1.2 ± 1.8 (57) | 1.4 ± 1.9 (27) | 1.0 ± 1.8 (30) |
| Car                                            | 0.6 ± 1.2 (57) | 0.4 ± 0.6 (27) | 0.8 ± 1.5 (30) |
| Other sedentary work                           | 0.4 ± 1.3 (57) | 0.7 ± 1.7 (27) | 0.2 ± 0.5 (30) |
| Private                                        |             |        |        |
| Computer                                       | 0.9 ± 0.8 (57) | 0.8 ± 0.6 (27) | 1.0 ± 0.9 (30) |
| TV                                             | 2.0 ± 1.1 (57) | 1.8 ± 1.0 (27) | 2.2 ± 1.2 (30) |
| Reading                                        | 0.6 ± 0.7 (57) | 0.5 ± 0.6 (27) | 0.7 ± 0.8 (30) |
| Car                                            | 0.5 ± 0.8 (57) | 0.3 ± 0.5 (27) | 0.6 ± 1.0 (30) |
| Other sedentary activities                     | 0.3 ± 0.7 (57) | 0.3 ± 0.7 (27) | 0.4 ± 0.7 (30) |

| Sedentary activities at weekends (Saturday and Sunday) |             |        |        |
|--------------------------------------------------------|-------------|--------|--------|
| At work                                                 |             |        |        |
| Mainly screen work                                       | 0.7 ± 1.7 (57) | 0.9 ± 1.7 (27) | 0.6 ± 1.7 (30) |
| Other office work                                        | 0.3 ± 0.9 (57) | 0.4 ± 0.9 (27) | 0.3 ± 0.8 (30) |
| Car                                                     | 0.1 ± 0.4 (57) | 0.1 ± 0.3 (27) | 0.1 ± 0.4 (30) |
| Other sedentary work                                     | 0.1 ± 0.5 (57) | 0.2 ± 0.6 (27) | 0.1 ± 0.4 (30) |
| Private                                                 |             |        |        |
| Computer                                                | 1.2 ± 1.2 (57) | 1.3 ± 1.4 (27) | 1.1 ± 1.1 (30) |
| TV                                                      | 2.7 ± 2.1 (57) | 2.4 ± 1.8 (27) | 2.9 ± 1.8 (30) |
| Reading                                                 | 1.0 ± 1.0 (57) | 1.0 ± 0.9 (27) | 1.1 ± 1.1 (30) |
| Car                                                     | 0.6 ± 0.9 (57) | 0.4 ± 0.7 (27) | 0.7 ± 1.0 (30) |
| Other sedentary activity                                | 0.5 ± 1.3 (57) | 0.7 ± 1.5 (27) | 0.3 ± 1.0 (30) |

| Most common reasons for physical inactivity<sup>a</sup> |             |        |        |
|--------------------------------------------------------|-------------|--------|--------|
| No time                                                 | 4.0, 1.0-5.0 (66) | 4.0, 1.0-5.0 (32) | 4.0, 1.0-5.0 (34)<sup>b</sup> |
| No motivation                                           | 3.0, 1.0-5.0 (66) | 2.0, 1.0-5.0 (33) | 4.0, 1.0-5.0 (33)<sup>b</sup> |
| Health reasons                                          | 2.0, 1.0-5.0 (68) | 2.0, 1.0-5.0 (34) | 2.0, 1.0-5.0 (34)<sup>b</sup> |

(Continues)
population. This might be because mental HRQOL is less affected by diabetes mellitus than physical HRQOL.6

As expected, further limitations result from the retrospective nature of the study. Data acquisition was mainly based on self-reporting, making it more prone to errors, especially response and non-response bias. Our post-interventional online survey was conducted anonymously, so qualitative analysis of non-responders was not possible.

Clinical studies examining physical activity are often susceptible to selection bias. In our field test, efforts were made to reach patients with diabetes who would usually not seek exercise interventions. Treating GPs and diabetologists could actively enrol their patients directly close to their hometown to facilitate entry instead of referring them to a distant center. In general, it is difficult to reach socially disadvantaged populations for medical interventions.43 The DPD succeeded in recruiting participants with a balanced gender and age distribution. Nevertheless, it is noticeable that, compared to the general population, participants were predominantly of German nationality,44 reported German as their preferred language,45 and had an above-average level of education.44 However, various studies have shown that similar lifestyle interventions were also effective in socially disadvantaged groups.41,46

We need to stress that our study is application-oriented working with multiregional groups. Therefore, measures as expected in a clinical study would have drastically raised the organizational burden for participants and sports providers making this study impracticable. For future research, the objective assessment of individual fitness in terms of ergometric stress testing as well as the evaluation of pre- and post-exercise blood pressure and heart rate would be desirable. Also, anthropometric measurements like fat mass, lean mass, water content, and waist-to-hip ratio could enhance the informative value.

FIGURE 2 Pre- and post-interventional BMI is shown as boxplots according to the participants’ BMI classification at baseline (x-axis). The median is represented as a thick line. The box delineates the first and third quartiles, and whiskers show minimum and maximum values, except for outliers marked with a dot°. Tested for by Analysis of Covariance (ANCOVA), the change in BMI differs significantly between groups, with the greatest reduction being present in obese patients (P < .001). Significant weight loss was observed in each group (significant in-group changes are marked by an asterisk* (P < .001))

TABLE 3 (Continued)

|                           | Total group       | Type 1          | Type 2          |
|---------------------------|-------------------|-----------------|-----------------|
| Subjective effect of the programa |                   |                 |                 |
| I feel physically healthier| 4.0, 1.0-5.0 (47) | 4.0, 1.0-5.0 (18) | 4.0, 1.0-5.0 (29)b |
| I feel mentally healthier  | 4.0, 1.0-5.0 (47) | 4.0, 1.0-5.0 (18) | 4.0, 1.0-5.0 (29)b |
| I feel more athletic       | 4.0, 1.0-5.0 (48) | 4.0, 1.0-5.0 (18) | 4.0, 1.0-5.0 (30)b |

Note: Data in n (%) or mean ± SD (n), unless otherwise indicated.

*aRepresented as median, range (n); accessed on a 5-point scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

*bCompared with type 1 diabetes by Wilcoxon test.

*Significantly different compared with type 1 diabetes (P < .05).

5 | CONCLUSION

Given the high rate of inactivity among people with diabetes mellitus, we investigated a structured running program targeted at a heterogeneous group of patients with diabetes. Significant positive effects on HbA1c and BMI were found, especially in the group of patients with a high cardiovascular risk due to obesity or elevated long-term blood glucose levels. In addition, positive effects on HRQOL can be assumed.

Future studies should examine whether the integration of exercise into everyday life and the observed health progress can be maintained in the long term. A comparison with a control group in the form of a waiting group design is recommended. Furthermore, additional efforts should be made to reach socially disadvantaged groups. Physical activity remains one of the most important influencing factors on cardiovascular morbidity of people with diabetes. A barrier-free integration into the daily life of as many
patients as possible is crucial to reduce cardiovascular risk in the long term.

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CONFLICT OF INTEREST
The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS
MG analyzed the data and wrote the manuscript. CJ supervised the process of analysis and provided methodological and interpretational guidance. MS, MG, and CJ contributed to data acquisition. All authors critically revised the manuscript for important intellectual content. All authors reviewed and approved the final submitted manuscript.

ETHICAL APPROVAL
Ethics approval was granted by the Sports University of Cologne for the ethic request with the number 059/2021.

For all subjects, written informed consent was obtained prior to the intervention.

DATA AVAILABILITY STATEMENT
The data set used for our analysis is accessible upon reasonable request to the corresponding author via Max. Golka@alumni.uni-koeln.de.

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