Case Report

A 12-Week Supervised Exercise Therapy Program for Patients with Diabetic Foot Ulcers: Program Development and Preliminary Feasibility

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Abstract

Exercise therapy helps improve glycaemic control and insulin sensitivity and may be relevant in treating patients with diabetic foot ulcers (DFUs). This study describes the development of a 12-week exercise therapy program for patients with DFUs and the preliminary feasibility of the program focusing on the program's inclusion, adherence, and safety. The development process is built on knowledge from a published systematic review on exercise for people with DFUs and a grounded theory study on the main concerns of people with DFUs regarding physical activity. The development involved doctors, wound care nurses, podiatrists, and feedback from patients and physical therapists using semi-structured interviews. The program was designed as a combination of aerobic and resistance training exercises. The aerobic exercise phase on the stationary bike of 30-minute duration was aimed at a moderate intensity. Resistance exercises were conducted with a 15-repetition maximum approach (four to five sets per trial) throughout the 12-week period. Three patients were included and received the exercise intervention. Except for recruitment and retention rates, acceptance levels were met for all other research progression criteria. Patients found the intervention relevant, wanted further guidance on continuing exercising, and would have liked the intervention closer to their home for example, a municipality setting. Although the exercise therapy program for patients with DFUs was developed in a thorough process with the inclusion of available evidence and the involvement of patients and other stakeholders conclusions on feasibility are limited due to the low recruitment rate. A reconsideration of the setting is needed in future exercise intervention studies.

Keywords

diabetic foot ulcers, lower extremity wounds, health-related quality of life assessments, wound assessment

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Background

Diabetes mellitus is associated with retinopathy, nephropathy, peripheral artery disease, heart disease, neuropathy, and diabetic foot ulceration (DFU). DFU is the most common and feared complication of diabetes and is associated with amputation and death.[1,2] Patients living with a DFU are often required to refrain from bearing weight on their affected limb,[3] leaving some patients immobile for weeks, months, or even years.[4] Such immobility contradicts diabetes guidelines, where exercise therapy is a cornerstone of treatment.[5] Living with restrictions on activity and movement is hard to accept by patients[4,6] who might ignore the severity of the situation and thus regard having a DFU as a "bump in the road" in their life (Aagaard 2021, unpublished manuscript, August 2022).

Guidelines for treating and preventing diabetic foot complications from the International Working Group on the Diabetic Foot (IWGDF) include the management of diabetes, integrated foot care, patient education, and self-management of foot care.[7] These guidelines do not include physical activity and exercise, despite their importance in the treatment of diabetes.[8] On a biological level periods of exercise have been found to lead to a significant improvement of important ulcerative risk factors,[3,9,10] and play a supporting role in wound healing of healthy human adults and patients with chronic leg wounds[11–13] as long as the adherence rates to exercise are high.[14] Including exercise therapy in the treatment of a DFU could be relevant since it helps improve glycaemic control and insulin sensitivity, blood pressure, cardiovascular events, and mortality rates[15,16] and has been found to increase health-related quality of life (HRQoL) in people with diabetes.[8] The latter is of key importance to people with DFUs, as living with DFU has been reported to be associated with reduced mobility, depression, and overall low HRQoL.[17–19] Nonetheless, recent systematic reviews published on the benefits and harms of exercise therapy for patients with a DFU[20,21] conclude that the safety profile of exercise in the management of DFUs is unclear since the current quality of evidence is low and based on randomized controlled trials with a high risk of bias. Moreover, different exercise regimens have previously been prescribed and adherence to exercise is low or unclear.[20] This diversity and lack of consensus on the optimal exercise prescription is not surprising given a historical DFU treatment recommendation of bed rest and/or wheelchair use[22] and avoidance of weight-bearing in general.[3] This study aimed to describe the development of a 12-week exercise therapy program for patients with DFUs and the preliminary feasibility of the program focusing on the program's inclusion, adherence and safety.

Methods

Study Design

The development process followed the Medical Research Council guidance for the development of complex interventions[23] and was reported according to the Guidance for the reporting of intervention Development (GUIDED) recommendations.[24]

A feasibility study with pre-determined progression criteria based on recommendations for designing high-quality feasibility studies[25] was planned. However, we only succeeded in including three patients, limiting any conclusions on feasibility. Hence, in this paper, we only report on the methods and results of the semi-structured interviews with patients and physical therapists. To increase transparency, the methods of the planned feasibility study and the preliminary results from this are presented in appendix 1

Exercise Therapy Program Development

The development process included a systematic review of existing literature on exercise for people with a DFU,[20] a qualitative grounded theory study on the main concerns of people with a DFU regarding physical activity (Aagaard 2021, unpublished manuscript, August 2022), and involved relevant stakeholders including DFU patients, doctors, wound care nurses, podiatrists, and physical therapists to integrate their needs and perspectives.

An initial 12-week supervised exercise program aiming to increase the blood flow and thereby oxygenation to the

Table 1. Expected Mechanisms of Action.

Aim	Mechanisms of action	Expected outcomes
To improve health-related quality of life with concurrent positive effects while not negatively influencing the size of the DFU.	Physical factors: improving blood flow to the DFU, balance, cardiorespiratory fitness, strength, and flexibility Psychological factors: encouraging adherence to an exercise routine and supporting activities of daily living and physical functioning.	Improved health-related quality of life Improved blood flow to extremities Improved muscle strength Improved physical function Improved self-rated health Reduced burden of illness

Abbreviation: DFU, diabetic foot ulcer.

peripheral tissue through cardiovascular fitness, strength, and endurance training[26,27] with as little weight bearing on foot soles as possible, as recommended by local wound care nurses, doctors, and Danish physicians[28] was developed in close collaboration with the authors and four clinical physical therapists with 3–21 years of experience in the treatment of post-operative and acute orthopedic rehabilitation, joint injury, and musculoskeletal disorders.

Based on physical therapists' discussions and pre-testing at the first intervention session, the two-legged knee extension was changed from using an elastic band to a weight manchet due to discomfort from the elastic band, and the fear of shear damage to the patients. Other than that, the exercise program was not changed from the initial version. Table 1 shows the expected mechanisms of action of the 12-week exercise therapy program.

Recruitment of Patients

The staff (doctors, nurses, and podiatrists) at the multidisciplinary outpatient wound care clinic screened patients with DFUs. Potential patients were contacted by the first author and invited to a physical meeting.

Inclusion Criteria. Patients with diabetes above 18 years of age with chronic DFUs located distal to the malleoli were considered for inclusion. Patients had to be prescribed a therapeutic sandal, or an orthopedic specialist shoe (see appendix 2) adapted to foot deformities with stiff outsoles and customized insoles offloading the DFU made by an orthopedic technician.

Exclusion Criteria. Patients were excluded if they had (1) dementia or other cognitive impairments; (2) gangrene, osteomyelitis, infection, or acute phase Charcot arthropathy in the index extremity; (3) were wheelchair-bound; (4) were prescribed with or using a walker boot; (5) were unable to understand Danish.

Infection was defined according to the criteria of the Infectious Diseases Society of America and IWGDF.[29,30]

The Number Needed to Recruit

Because effectiveness was not evaluated, a formal power calculation was not performed. Julious[31] recommend including 12 patients in feasibility studies based on the rationale for a feasibility study, regulatory considerations, and statistical considerations about a precise and representable mean and variance. However, to make sure that enough patients were included, a total of 15 patients were planned to be recruited.

Patient and Physiotherapist Interviews

Semi-structured interviews with the patients were conducted at the end of the 12-week exercise program. An interview topic guide with open questions on the acceptability of assessment procedures, treatment experience, and feedback about the supervised sessions and potential adverse events was used. The themes that emerged during the interview were followed by probing questions and if needed, the interviewer made the open-ended question more focused, for example, "Which changes in your daily life (if any) have you experienced after finishing 12 weeks of exercising?." Physiotherapists were continuously interviewed after each exercise session and at the end of the 12-week exercise program. Their interview response covered whether specific exercises were applicable to this population, including handling the progression of exercise intensity and exercise and load modification. Finally, both patients and physiotherapists were asked whether they would participate in an exercise therapy program again and asked to suggest potential improvements to the study design and procedures. All physiotherapist and patient interviews were conducted in Danish. Data was recorded through notes and descriptive field notes and qualitative content analysis[32] was used to analyse the data. Each interview was conducted behind closed doors and lasted between 30 and 60 minutes. All interviews were conducted by the first author.

Results

The Final Exercise Therapy Program

The description of the exercise therapy program adheres to the template for intervention description and replication checklist[33] and the Consensus on Exercise Reporting Template items[34] (appendix 3).

The exercise therapy program was a 12-week group-based, supervised exercise therapy program (2 exercise sessions per week of 60 minutes each). Present at each exercise session for supervision was the principal investigator and one physical therapist member of the team. The program was designed as a combination of aerobic and resistance training exercises. Each exercise session started with a warm-up phase (10 minutes on a stationary bike with little to no resistance), followed by an aerobic exercise phase (20–25 minutes of interval-based cycling on the stationary bike) and finally strengthening exercises (two-legged knee extension, pelvic lift, lateral pull-down, biceps curl, and resistance band flyers and resistance band rows; appendix 4). The aerobic exercise phase on the stationary bike of 30 minutes duration aimed at a moderate intensity (Heart rate intensity 40%–60% or rating of perceived exertion: somewhat hard) as recommended to people with peripheral neuropathy.[35,36] To measure dyspnoea and perceived exertion during the stationary bike session the Dalhousie Dyspnoea and Perceived Exertion Scales[37] were used due to their additional pictorial scale to depict leg exertion/fatigue, which was key since some DFU patients undergo surgical

treatment with Achilles' tendon lengthening and gastrocnemius recession[38] and the effect of stationary cycling after this treatment is unclear. Resistance exercises were conducted with a 15-repetition maximum approach (four to five sets per trial) throughout the 12-week period. Since the patients were untrained and novices in the exercises, light loads coupled with higher repetitions to increase aerobic power and muscular endurance were used.[39,40] During the exercise sessions, the physical therapist gave the patients feedback to ensure proper performance of the exercises and to maintain their motivation. Patients were encouraged to increase speed and/or resistance on the stationary bikes as well as to progress training loads during the strengthening exercises while maintaining proper technique as assessed by the physical therapist.[40] Any adverse events were registered at the start of each exercise session and patients were instructed to check their feet on the night after the exercise session. Feedback on the 12-week period from patients covered municipality podiatrist's visits, outpatient visits at the hospital, home nurse visits and self-monitoring from patients.

Patient Inclusion

Fifteen patients were assessed for eligibility from September 1, 2021, to April 1, 2022, and three male patients were included (Figure 1).

The main reason for not being included was patients declining to participate ($n = 8$). When asked to elaborate, one was enrolled in municipality heart and post-surgery rehabilitation programs, five found the planned 24 exercise sessions and the travel times twice a week, too burdensome whereas two were in jobs that made participating during daytime impossible.

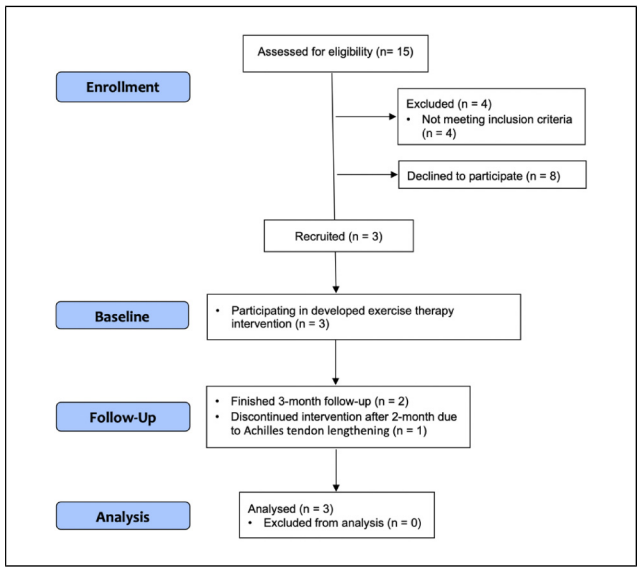

Figure 1. The CONSORT (Consolidated Standards of Reporting Trials) flow diagram.

The demographic characteristics of the three included patients are presented in Table 2 and the preliminary feasibility outcomes can be found in appendix 1.

Patient and Physiotherapist Interviews

None of the patients had been offered exercise therapy throughout their time with a DFU before this study, and although some patients found the exercise therapy demanding, they all found it relevant. All three patients found exercise therapy two times a week appropriate but would have liked the exercise period to span for more than 12 weeks. At the end of the study, all three asked for advice on how and where to continue their exercise routines. When asked, all patients agreed that they would have preferred that the intervention took place closer to their home for example, a municipality setting.

When asked about the timing of the exercise intervention and their DFU history and treatment, all patients stated, that they were more mentally ready to participate in exercise now, than at the DFU debut. They reported somewhat negligence regarding what bodily consequences a DFU might give them over time, hence they had high hopes for complete healing after initial representation in the clinic.

All patients stated that doing regular exercise twice a week, gave them more energy and boosted their capacity. One patient resumed his passion for bowling 6 weeks into the study, whereas one decided to spend one-weekend cycling 10 km to test his bodily "limits" resulting in delayed muscle soreness for one week thereafter. He later stated that he would have only done so, after regular cycling on a stationary bike, and ongoing progression in the study.

The patients described that the physical therapists were supportive and ensured that the exercise therapy program was pro- and regressed the individual patient when needed. The patients considered the individual exercises feasible, relevant, and effective. The ongoing supervision was found important by patients, hence physical therapists could adjust the exercises if performed incorrectly. Although, physiotherapists described the patients: "as any other untrained geriatric patient with little exercise motivation and technique." They described patients' neuropathy and fear of inflicting a new wound on patients as a key focus in exercise situations. One described that she had to be "the patient's extra set of eyes" when performing exercises to ensure that patients did not accidentally fall or bump into things.

Discussion

This paper outlines the process undertaken to develop and evaluate the preliminary feasibility of a 12-week exercise

Table 2. Demographic Characteristics.

Variable	Pt. 1	Pt. 2	Pt. 3
Gender	Male	Male	Male
Age, years	78	63	70
Body mass index, kg/m^2	28.4	33.2	24.8
Diabetes type	2	2	2
Duration of diabetes, months	300	252	192
Duration of DFU, months	29	4	3
History of DFU, numbers/healed	3/3	3/3	3/3
Disease history	Diabetic peripheral neuropathy Hypertension Hyperlipidemia Erysiphales Skin cancer	Diabetic peripheral neuropathy Atrial fibrillation Hypertension Apoplexy cerebri	Diabetic peripheral neuropathy Hypertension Orthostatic hypotension
Prior surgery of index foot/leg	2 × Achilles tendon lengthening Percutaneous tenotomy of facia plantaris	1 × Achilles tendon lengthening Percutaneous tenotomy of facia plantaris	2 × Achilles tendon lengthening Percutaneous tenotomy of facia plantaris
Exercise history	No	Apoplexy cerebri rehabilitation	No

therapy program for patients living with a DFU. The developed exercise therapy program included a combination of aerobic and resistance training exercises. However, conclusions on feasibility are very limited by the low recruitment rate, a reconsideration of the setting is therefore needed in future exercise intervention studies.

The recruitment rate in this study did not meet the predetermined progression criteria. Similar recruitment issues have been found in other exercise studies on DFU patients.[41,42] One potential reason for the low recruitment rate might be due to "gatekeeping" from the healthcare professionals identifying and approaching patients.[43] Skepticism from the recruiting healthcare staff on the safety of exercise for DFU patients might have restricted access to patients who were potential trial patients. A way to identify if healthcare professionals engage in gatekeeping is through qualitative research. Hence, this can help develop information to guide recruiting practices and address inappropriate "over caution."[43] Another reason could be the hospital setting far from patients' homes and the time of day offered for the exercise intervention. Feedback from included patients, eligible patients declining to participate and research on people living with multimorbidity[44] indicates that these are barriers to engaging in exercise. Further testing is required to explore the best possible exercise setting for patients with a DFU and ways to improve inclusion rates.

Even though the interviews and ongoing feedback from patients and physiotherapists did not result in many changes to the exercise therapy program, they contributed key information and perspective on the program and future feasibility. First, individual exercises and progression were found relevant and effective. Second, supervision from physical therapists was considered important. Third, patients described finding pleasure and meaning in adopting exercise therapy in their weekly routine which, in turn, may have reduced the DFU burden by improving capacity as similarly reported in type-2 diabetes patients.[45] Fourth, physiotherapists' lack of knowledge in exercising the patient population indicates an educational need. And finally, the interviews highlighted the problem of the setting and thereafter recruitment issues and reinforced a need to rethink the setting in which exercise should be provided to this patient population.

A strength of the study is the standardized, transparent, and precisely described exercise therapy program for patients with a DFU that can easily be adapted for other settings[46] as well as the level of engagement and involvement from physiotherapists and supervision of patients during exercise interventions. As is the iterative development of the intervention with much discussion, questioning and refinement of individual components before they were brought together as a single coherent intervention. Although the development process is seldom reported[47] it is highly important to be able to understand the success (or failure) of an intervention and to enable potential replication.

The study has some limitations. The most important was that this study did not reach the target sample size due to challenges with recruitment limiting conclusions on the feasibility of the intervention developed. Considerations on improving this and including exercise in a more flexible setup to account for work hours or transport times should be a key focus in future studies as it will influence the future real-life implementation of exercise for this population. Secondly, only men with similar DFU complications were included in the study. DFU complications and comorbidities might

physically affect patients differently and thereby their ability to participate in exercise therapy as such, it is important to include individualized modifications to an exercise program. Thirdly, only patients using a therapeutic sandal or orthopaedic specialist shoe were included in this study. While the walker boot or total contact cast is considered the preferable method of off-loading in DFU parents. This inclusion criterion was guided by results from a qualitative grounded theory study on the main concerns of people with a DFU regarding physical activity (Aagaard 2021, unpublished manuscript, August 2022). Where patients describe their ability and willingness to participate in physical activity increased after using these off-loading devices.

Lastly, are the outcomes chosen in the study, hence no recommended set of outcomes was available for DFU patients and with the results being inconclusive further studies including qualitative research with patients[48] will be required to identify the outcomes most relevant for patients before future feasibility testing.

Conclusions

This study developed an aerobic and resistance exercise therapy program for patients with DFUs in a thorough process building upon a systematic review, a qualitative study and involving patient- and therapist feedback and other relevant stakeholders. Conclusions on feasibility are limited by the low recruitment rate, which calls for a rethink of future exercise intervention setups in the population. Future feasibility trials are required in which the developed program is adapted and tested in other settings to understand if exercise is feasible and relevant in the rehabilitation of patients with a DFU.

Ethical Considerations

The study complied with the Declaration of Helsinki and was approved by the Danish Data Protection Agency (Region Zealand j.nr. REG-075-2021), the Regional Committees on Health Research Ethics for Region Zeeland (Region Zealand j.nr. SJ-928), and prospectively registered in clinicaltrials.gov (reference ID: NCT05101473).

Patients provided both oral and written informed consent before inclusion and the International Committee of Medical Journal Editors' Recommendations for the Protection of Research Patients were followed.

Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

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