

Maintaining Changes in Physical Activity among Type 2 Diabetics - A Systematic Review of Rehabilitation Interventions

Thomsen, Simon; Kristensen, Gustav David Westergaard; Jensen, Nynne Weigelt Herløv; Agergaard, Sine

Published in:
Scandinavian Journal of Medicine & Science in Sports

DOI (link to publication from Publisher):
[10.1111/sms.13951](https://doi.org/10.1111/sms.13951)

Publication date:
2021

Document Version
Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Thomsen, S., Kristensen, G. D. W., Jensen, N. W. H., & Agergaard, S. (2021). Maintaining Changes in Physical Activity among Type 2 Diabetics - A Systematic Review of Rehabilitation Interventions. *Scandinavian Journal of Medicine & Science in Sports*, 31(8), 1582-1591. <https://doi.org/10.1111/sms.13951>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

MR SIMON THOMSEN (Orcid ID : 0000-0002-2440-3424)

Title: Maintaining Changes in Physical Activity among Type 2 Diabetics – A Systematic Review of Rehabilitation Interventions

Running head: Maintaining PA behaviour in Type 2 diabetics

Authors:

Simon Thomsen

Gustav David Westergaard Kristensen

Nynne Weigelt Herløv Jensen

Sine Agergaard (corresponding author)

sine@hst.aau.dk

+4540472390

Institutional affiliation (all authors):

Sport Sciences, Department of Health Science and Technology, Aalborg University, Denmark

Niels Jernes Vej 12, 9220 Aalborg East, Denmark

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1111/SMS.13951](#)

This article is protected by copyright. All rights reserved

Acknowledgements:

The authors would like to thank consultants Jesper Torp Nielsen and Lars Lejbølle of The North Denmark Region for assisting in outlining the difficulties associated with Type 2 diabetes mellitus rehabilitation and librarian Jette Thise Pedersen from the Aalborg University Library for assisting in the literature search process.

Data availability:

All data used for analysis are available in the articles referenced, or in supplemental material provided with the online versions of the articles.

Abstract

The prevalence of Type 2 diabetes mellitus (T2DM) is increasing worldwide and physical activity (PA) is a suitable way of preventing and managing the disease. However, improving long-term levels of PA in people with T2DM is a challenge and the best approach to rehabilitation in this regard is unknown.

With the aim of outlining the existing knowledge regarding the maintenance of active lifestyles among people with T2DM after rehabilitation programmes and gaining knowledge about options and challenges for their long-term engagement in PA, a systematic review of original research articles assessing PA after rehabilitation programmes was conducted. Two-thousand-two-hundred-and-fourty-one articles were identified through PubMed or secondary sources and subjected to various inclusion criteria. Only articles published between the 1st of January 2000 and the 30th of June 2020 were considered. Additionally, the minimum time frame from intervention start to last PA assessment was 6 months and only articles based on interventions performed in Europe were included.

The review was based on eighteen randomised controlled trials, four randomised trials without control and four case studies. The 26 articles described 30 interventions that were categorized as *personalized counselling*, *generalized teaching*, *supervised exercise* or a *combination of personalized and generalized interventions*. Statistical and narrative syntheses revealed no clear pattern regarding the effectiveness in eliciting maintained changes in PA.

However, across categories, individual involvement, goal setting, social support and the formation of habits are argued to be important components in sustaining PA and relieving challenges associated with the transition out of rehabilitation programmes.

Keywords:

Exercise, Self-care, Lifestyle changes, Health care, Adherence, Compliance

Introduction

Diabetes is an increasing problem worldwide and it has recently been estimated that 415 million people suffer from the disease.¹ Of these, more than 90 % are accounted for by Type 2 diabetes mellitus (T2DM).¹ In Denmark, the number of persons diagnosed with T2DM has almost tripled from 82,150 in 2000 to 227,525 in 2016.² Furthermore, it is estimated that close to 300,000 Danes suffer from pre-diabetes, a precursor for T2DM³ and that approximately 60,000 Danes suffer from T2DM without being diagnosed.³

The increase in the number of people suffering from T2DM is highly concerning as T2DM is associated with various diseases and complications.⁴ Among the complications often associated with T2DM are retinopathy,⁵ neuropathy,⁶ nephropathy⁷ and cardiovascular diseases.⁸ Furthermore, the overall mortality among people with T2DM is approximately twice as high when compared with people without the disease.⁴

In addition to the individual consequences associated with diabetes, immense economic implications apply on a societal level. In Denmark, at least 4.27 billion euro were spent in direct relation to diabetes in 2011,⁹ and the cost is expected to increase to between 9.98 and 13.26 billion euro by 2040.¹⁰ The three main expenses associated with diabetes are health care costs, nursing costs and lost productivity.⁹

Among the most prevalent reasons for the development of T2DM is a lack of physical activity (PA).^{11,12} Thus, regular participation in PA, understood broadly as bodily movement resulting in expenditure of energy, may serve as an effective means to prevent the development of T2DM. Consequently, Jeon et al¹³ have shown that regular participation in PA of moderate intensity reduces the relative risk of developing the disease to approximately 0.7 when compared with a more sedentary lifestyle; i.e. the risk is reduced by 30 %.

Besides the preventive effect, regular participation in PA has been shown to positively affect the health of those already diagnosed with the chronic T2DM condition. For instance, the glycaemic

control, which is the ability to keep blood glucose levels within the normal range, is aided by PA.¹⁴ Furthermore, PA is positively associated with numerous psychological factors such as mood, well-being and quality of life, and it reduces the risk of anxiety and depression.¹⁵ These psychological factors are especially relevant for people with diabetes as the disease is, for instance, associated with an increased risk of developing anxiety.¹⁶

Even though the benefits of participating in regular PA to prevent and manage T2DM are scientifically evident, they do not always translate to pertinent behaviour. In a review of 47 randomised controlled trials on the topic, Minet et al¹⁷ concluded that the glycaemic control among people with T2DM improved significantly following self-care management treatment focusing, among other things, on exercise. However, the study also showed the effect size of such treatment was largest when measured immediately after an intervention, and gradually decreased over time.¹⁷

This gradually decreasing effect is rather unfortunate when considering the general approach to rehabilitation. In Denmark, programmes vary across different municipalities¹⁸ but are generally designed to contain supervised sessions of PA with varying intensities lasting approximately 3 months.¹⁹ Afterwards, participants are sometimes referred to activities in their local communities and invited to infrequent follow-up sessions but are otherwise largely left to themselves, and not surprisingly the effects of interventions often decline or disappear over time,¹⁸ underlining the need for an improved, science-based approach to T2DM rehabilitation.

The aim of this study was to outline the existing knowledge about the maintenance of active lifestyles after rehabilitation programmes among people with T2DM. The paper will contribute with knowledge about options and challenges regarding long-term engagement in PA for the benefit of people with T2DM, health professionals and institutions involved in T2DM management and rehabilitation. Thus, the present systematic literature review aims to answer the question, *How should interventions promoting physical activity for Type 2 diabetes mellitus treatment and management be structured to best support long-term changes in behaviour?*

Behaviour in relation to physical activity is a complex area spanning different scientific fields such as sociology, psychology and neuroscience, and to understand behaviour in health science, some focus on environmental conditions^{20,21} while others pay attention to individual motivation^{22,23} or habits.^{24,25} All these views are drawn upon to provide a nuanced view of the options and challenges associated with T2DM rehabilitation.

Material and methods

The present article is based on a systematic review of scientific literature regarding the initiation and maintenance of a physically active lifestyle among people with T2DM. To be considered eligible for inclusion in the review, the studies were subjected to a series of criteria.

Eligibility

Firstly, only studies published in the year 2000 or later were considered in order to outline the most current research. Additionally, only publications in which people with T2DM participated in a rehabilitation programme and in which some outcome(s) regarding levels of PA were assessed at least 6 months after initiation were included. The minimum of 6 months was chosen as exercise programme participation rates have been shown to decrease drastically within the first 6 months after starting a new regime.²⁶ Thus, 6 months was deemed the minimum time frame by which *maintenance* could be assessed in any capacity.

Furthermore, the inclusion was limited to studies published in English or Danish, and only studies conducted in Europe were considered as social, political and cultural differences across continents may impact the transferability of evidence in health care.²⁷

Search strategy

The review is based on articles retrieved through PubMed, Google Scholar and reference lists. The primary search was limited to one database as depth was prioritized over breadth, and PubMed was chosen as the primary source of knowledge as it was deemed the most relevant database for the purpose of this study. The systematic review was conducted using a building block search strategy in PubMed consisting of three blocks that were connected using the Boolean operator 'AND'. Each

block consisted of a key facet of the research question; T2DM, PA or maintenance (of level of PA). The blocks were built using various MeSH terms and text words regarding the specific facet, all connected with the Boolean operator 'OR'. An overview of the building blocks can be seen in table 1.

Data abstraction

The original search was concluded on the 17th of October 2018 and yielded 1,997 results when filtering out articles published before the 1st of January 2000 and articles concerning animal studies. Titles and abstracts were then screened by one of the authors and 1832 studies that were indisputably unsuitable according to set criteria were excluded. If articles were deemed possibly relevant or if any doubt existed, they qualified for additional probing. Thus, 165 articles were discussed among the first three authors. Of these, 152 were excluded upon further review, many of them quickly and simply due to geographical origins outside of Europe, and 13 articles were found to fulfil all inclusion criteria. In addition to the 13 included studies, another 15 studies were identified and included through examination of reference lists of relevant literature reviews identified in the search. Lastly, an unstructured Google Scholar search contributed with one article.

The final step in the meticulous selection process was a quality assessment of the 29 articles initially included. The quality was assessed by the first three authors using study design-specific checklists on the reporting of intervention approach and information collection and analysis²⁸ and by evaluating the biases associated with certain choices and conditions identified as essential in these checklists. Six articles initially included were excluded due to unsatisfactory descriptions of methods and/or results such as unclear participant allocation, unclear outcomes and insufficiently described interventions,²⁹⁻³⁴ and one article was excluded as its focus on practical implementation rather than outcome evaluation made data difficult to interpret in relation to the aim of this review.³⁵ We did not contact authors for missing information.

The systematic PubMed search was updated on the 30th of June 2020, identifying an additional 244 records. The same steps were then completed and four additional articles qualified for quality assessment and were included.

Data synthesis

The articles included in the present review were analysed descriptively with inspiration from the *Guidance on the conduct of narrative synthesis in systematic reviews*.³⁶ This was done by assessing and grouping the described interventions according to various characteristics such as setting, target population, intervention length and overall approach, looking for patterns in relation to resulting PA outcomes. During this process, done collectively by the first three authors, four overall types of interventions emerged; personalized counselling interventions, generalized teaching interventions, supervised exercise interventions, and a combination of personalized counselling and generalized teaching. These categories constitute the *frame* within which the syntheses presented in the results section were analysed.

Quantitative PA outcomes were assessed statistically. If repeated measures data were reported for the intervention group(s), these data were used to determine the effects of the intervention(s). If not, data comparing interventions to control groups were used instead. This hierarchy of data was chosen as control groups were seldomly actual control groups and commonly alternative interventions labelled *standard* or *usual care*, making comparisons difficult to interpret. If the selected data showed no significant difference, they were marked as “→” in tables 2-5. If a significant difference was reported,

“↑” was used to indicate a significant increase in PA, followed by a Cohens d-type measure of effect size. Depending on the available data, the effect size was calculated with one of the following formulae:

- For pre-post data, $d_1 = \frac{\mu_{T,post} - \mu_{T,pre}}{\sigma_1}$
- For treatment-control data, $d_2 = \frac{\mu_{T,post} - \mu_{C,post}}{\sigma_2}$
- For time-group-interaction data, either $d_3 = \frac{\Delta\mu_T - \Delta\mu_C}{\sigma_3}$ or $d_4 = \frac{\Delta\mu_T - \Delta\mu_C}{\sigma_4}$

Where μ is the mean, $_T$ refers to a treatment group, $_C$ refers to a control group, $_{post}$ refers to post-intervention measurements, $_{pre}$ refers to baseline measurements, Δ refers to the mean difference between baseline and post-intervention measurements, σ_1 is the pooled standard deviation (SD) of pre and post data in a treatment group, σ_2 is the pooled SD of post data in a treatment group and a control group, σ_3 is the pooled SD of pre-post mean changes in a treatment group and a control group, and σ_4 is the pooled SD of a treatment group and a control group, based on the average SD of pre and post within each group.

In some instances where SDs were not directly reported, we calculated these from 95% confidence intervals using the formula: $SD = \sqrt{n} * \frac{upper\ limit - lower\ limit}{3.92}$, or from standard error (SE) using the formula: $SD = SE * \sqrt{n}$.

If data was available to calculate effect size with more than one of the described formulae, they were prioritised as follows: $d_1 > d_3 > d_4 > d_2$. When several distinct, quantitative measures of PA were available, objective measures (accelerometer etc.) were chosen over subjective measures (questionnaires).

This overall method for outcome assessment was used to make various distinct designs and outcome measures of PA comparable to some extent. The following sections outline the effectiveness of different approaches to rehabilitation regarding maintained improvements in PA levels.

Results

The selection process yielded 26 research articles³⁷⁻⁶² describing 30 distinct interventions. Three articles were concerned with a single intervention⁴³⁻⁴⁵ and two other articles were concerned with another one,^{39,40} while six articles evaluated multiple interventions.^{37,38,46,50,53,55} The articles included 18 randomised controlled trials, four non-controlled trials and four qualitative or mixed methods case studies of people with T2DM participating in large programmes.

Study characteristics

Among the included studies, the publication year ranged from 2003 to 2019. The mean of the reported mean ages of participants was 60.3 (2.7) years, and time between T2DM diagnosis and intervention participation varied between a few months and several years. Of the 30 distinct interventions, 14 had an individual approach to rehabilitation, while 11 used group-based programmes and 5 used a mixture of the two. The mean duration of the interventions was 8.1 (6.0) months, the mean time from the intervention initiation to the last point of PA assessment was 13.9 (7.1) months, and the mean time gap from intervention end to last PA assessment was 6.1 (6.8) months (interventions continuing beyond last point of assessment counted as 0).

Lastly, the overall approach to rehabilitation in the studies was categorized as either personalized counselling interventions, generalized teaching interventions, supervised exercise interventions or a combination of personalized counselling and generalized teaching, as described in the methods section. Below, syntheses of the articles are presented by category followed by a discussion of patterns across all studies.

Personalized counselling interventions

The interventions in this category³⁷⁻⁴⁷ were defined by a personalized approach to rehabilitation where the contents and recommendations were weighed against personal interests, wishes, competences, etc. The main characteristics and results of the interventions categorized as personalized counselling are presented in table 2. Based on the 11 studies included, personalized counselling interventions tended to have positive effects on PA at least 6 months after intervention initiation. Across all the studies, people with T2DM were the primary target of intervention, an individual approach was taken and

interventions lasted between 3 and 12 months. A more thorough view of the intervention structures revealed various similarities across studies. Most interventions used an initial face-to-face consultation with a nurse or physician regarding PA and goal setting followed by phone calls for support and goal evaluation. Two studies^{37,38} had a marginally different approach combining PA counselling with diet counselling and conducting face-to-face follow-up sessions as opposed to phone calls. Andrews et al³⁸ showed positive effects of this approach at both 6 and 12 months when compared with *usual care* controls, while Malpass et al³⁷ qualitatively explored the mechanisms behind these results, showing that a broad perspective on management including both PA and diet may elicit increased confidence in one's ability to manage T2DM, and that additional tools for controlling blood glucose are perceived as helpful rather than counterproductive.³⁷ Effect size calculations revealed that all studies in this category with measurements at multiple times showed a decrease in effect over time, even if significant improvements were maintained. This is in line with what has previously been reported regarding glycaemic control.¹⁷

Generalized teaching interventions

This category was defined by interventions⁴⁸⁻⁵² mainly based on providing general information to groups of people with T2DM. Table 3 shows the main characteristics of interventions labelled as generalized teaching. In this category, results were mixed as some studies showed positive effects of generalized teaching interventions on PA while others showed no significant effects. The interventions in this category were characterized by their direct targeting of people with T2DM while also conducting the teaching in group settings. Furthermore, intervention periods were generally short resulting in relatively large gaps between intervention endpoint and PA outcome assessments.

Looking thoroughly at the intervention approaches, some studies focused on educating participants in T2DM consequences and management strategies such as diet and PA.⁴⁸⁻⁵⁰ As seen in table 3, this approach tended to be less effective in evoking sustained changes in PA after at least 6 months, although Deakin et al³⁹ did show a marginally positive effect.

Additionally, two studies investigated a more motivation-oriented teaching approach focusing on the importance of self-efficacy or empowerment.^{50,51} Kulzer et al⁵⁰ reported significant positive effects of this approach while Moreno et al⁵¹ found no effect on most outcomes related to PA.

Finally, Rise et al⁵² found that obtaining new knowledge was an important factor for the initiation of lifestyle changes. However, other factors such as social support, positive experiences and the formation of habits were more closely related to the maintenance of those changes in the long term.

Supervised exercise interventions

In this category, interventions⁵³⁻⁵⁷ were defined as consisting mainly of supervised exercise sessions, and the results of this approach are seen in table 4. The studies differed in settings as two had an individual programme, two were group-based and one was mixed. Furthermore, intervention durations varied between 4 and 25 months.

As in the previous category, the results were mixed with Gram et al⁵³ showing no effects of their 4-month supervised exercise interventions at 12 months compared with baseline. Nicolucci et al,⁵⁴ Gallé et al,⁵⁶ and Balducci et al⁵⁷ all found that their interventions based on supervised aerobic and resistance training significantly improved levels of PA. Nicolucci et al⁵⁴ assessed PA immediately after the intervention, meaning participants could show improvements by only following the supervised PA in the intervention. However, they also reported a significant increase in non-supervised PA in the intervention. However, they also reported a significant increase in non-supervised PA, albeit with a much smaller effect size. Balducci et al⁵⁷ offered three months of supervised exercise but spread over 25 months. This approach led to significant increases in PA at both 12, 24 and 36 months, although the effect size decreased slightly over time, as seen in most other studies.

The last study in this category, Praet et al,⁵⁵ differed by only reporting adherence rates during the year-long intervention of supervised walking or fitness. No significant differences were demonstrated in adherence rates between the groups, but the overall effectiveness in creating sustained improvements in PA levels was debatable.

Combining personalized counselling and generalized teaching

The last category is shown in table 5 and is defined by studies^{46,58-62} based on interventions containing a balanced combination of personalized counselling and generalized teaching. The interventions in this category differed in several aspects. Vissenberg et al⁵⁸ and Van Puffelen et al⁶² used a group approach and included spouses, friends, etc. of the participants with T2DM, whereas Thoolen et al,⁵⁹ Lindenmeyer et al⁶⁰ and Maindal et al⁶¹ were based on 12-week interventions with a more individual

approach. Thoolen et al,⁵⁹ Maindal et al⁶¹ and Van Puffelen et al⁶² mixed education on relevant topics (e.g. PA, diet, medication) with goal setting and group discussions in relation to those topics. Lindenmeyer et al⁶⁰ educated health professionals in listening and supporting, and both Lindenmeyer et al⁶⁰ and Kirk et al⁴⁶ provided participants with information and goal setting exercises as well as telephone support. In this category, again the results were mixed. Vissenberg et al⁵⁸ showed significant improvements in PA after 10 months, but changes were not maintained 6 months later. On the other hand, Thoolen et al⁵⁹ showed improvements in PA at 12 months compared with baseline while a very similar intervention in Maindal et al⁶¹ showed no effect after 36 months. Lindenmeyer et al⁶⁰ reported marginal improvements in PA in the intervention group at 12 months, partly attributing the changes to the strategic use of PA in self-management of blood glucose levels. Neither Kirk et al⁴⁶ nor Van Puffelen et al⁶² showed any significant increase in PA assessed three months after the end of their respective interventions.

Discussion

As evident in the syntheses presented above, rehabilitation programmes for people with T2DM include a diversity of approaches with corresponding diverse outcomes. Therefore, how programmes should be structured to support long-term changes in physical activity is not self-evident based on the categories we provide. In the following section, tendencies that cut across the presented categories will be discussed in order to better understand which elements to consider when structuring rehabilitation programmes for people with T2DM.

Through qualitative interviews with people with T2DM participating in a group-based educational programme, Rise et al⁵² highlighted the importance of social support in maintaining lifestyle changes, e.g., PA patterns. Correspondingly, Vissenberg et al⁶³ reported an improvement in general self-care behaviour (including exercise) after an intervention promoting social support among peers with T2DM, and Van Dyck et al⁴⁰ showed that social support from family was a consistent mediating factor for improvements in *intermediate-term* (12 months) PA among people with T2DM. These results might spur a belief that group-based programmes are generally preferable for the maintenance of lifestyle changes, but the present review does not support that notion. Looking at the quantitative results of the included trials, no clear association appears between group settings and the

improvement and maintenance of PA levels but rather an opposing tendency supporting a more individual or combined approach.

As peer support in groups of people with T2DM has previously been reported to positively affect self-management,⁶⁴ it is likely that the lack of evidence in the present review supporting this notion is not indicative of insubstantial effects of social support from peers. Rather, it may indicate the importance of tailoring interventions to the specific needs of each person as generally practiced in the included studies based on personalized counselling in which setting and evaluating personal goals were often focal parts.

In general terms, both social support and individual involvement are key motivational factors. For instance, the Self-Determination Theory⁶⁵ presents relatedness, competence and autonomy as the basic psychological needs associated with intrinsic and sustained motivation. By combining individual goal setting and a supportive group environment, the overall motivation and maintenance could possibly be enhanced as the personal involvement may elicit a feeling of autonomy, while social interaction with peers could aid the sense of relatedness. Thoolen et al⁵⁹ exemplified the value of an approach mixing individual and group sessions in eliciting and maintaining changes in PA. However, instead of focusing on motivation the objective of the intervention was to enhance participants' ability to cope with barriers preventing intentions from becoming sustained actions. Thus, Thoolen et al⁵⁹ recognized the possible disparity between motives and actual behaviour.

Another perspective on behaviour is that of habits. Orbell & Verplanken⁶⁶ investigated the role of habits in health behaviour focusing on cue-contingency and automaticity as predictors of behaviour; thus referring to an automated cue-response relationship as a crucial component of habitual behaviour. Elaborating the role of habits in health behaviour, they claim, "*Motivational models and persuasive appeals that encourage people to develop positive health related goals might more effectively lead to the development of habitually automated and sustained behaviours if they encourage repetition of behaviour in a stable context or in response to a stable cue*"⁶⁶

(p.381).

By underlining the need for stable contexts and stable cues in sustained behaviours, this theoretical view provides a framework for understanding the limited success of various rehabilitation

programmes in general and for people with T2DM specifically. During structured interventions, participants may learn new patterns of behaviour but are also provided with certain circumstances (e.g. training group) and cues (e.g. phone calls, leaflets, diaries) by which the behaviours are triggered. Thus, the discontinuation of these habitual triggers of PA after interventions could help us understand the difficulties associated with the transition from being an intervention participant to becoming responsible for your own health through self-care. Both De Greef et al³⁹ and Vissenberg et al⁵⁸ accentuated the difficulties associated with this transition as they reported that their respective programmes led to significantly positive effects on the levels of PA at the endpoint of their interventions, while these effects were significantly diminished 6 months after the interventions in both cases.

To summarize, an approach to rehabilitation where the participants partake in goal setting, receive social support and learn how to cope with barriers seems to be preferable for creating sustained changes in PA. Additionally, while supportive structures seem to be beneficial to long-term promotion of PA, these structures should be sustainable as PA engagement might be positively aided by cues provided in or by a certain context.

To provide a more systematic view of the effects of certain components of interventions, further research could explore the research question of the present study through the CALO-RE behaviour change taxonomy provided by Michie et al.⁶⁷

Limitations

The present study has some methodological limitations that should be acknowledged. Firstly, the inclusion of only one database in the primary search may have limited the number of records identified, and the fact that almost half of the records came from the secondary search reinforces this idea. Additionally, other databases such as PsycInfo or Embase may have broadened the type of records identified. The fact that titles and abstracts were initially screened by only one person could also be problematic, although we tried to alleviate the problem by being generous in this step, only excluding what was perceived as obvious noise.

Conclusion

Long-term maintenance of physical activity (PA) has proven to be a challenge for people with Type 2 diabetes mellitus (T2DM). In this systematic review, literature regarding the maintenance of PA after rehabilitation interventions conducted in Europe between 2000 and 2020 was retrieved through PubMed, Google Scholar and various reference lists. The searches led to the inclusion of 26 original articles describing 30 distinct interventions. Articles were categorized according to their overall intervention approach as either *personalized counselling*, *generalized teaching*, *supervised exercise* or a combination of *personalized counselling and generalized teaching*. Syntheses revealed no definite effects of the approaches on long-term (6+ months) PA as the results in all categories were mixed. Additionally, tendencies across categories were discussed, and individual involvement, goal setting, social support, coping with barriers and formation of habits stood out as influential factors in determining long-term PA. Furthermore, the difficulties associated with the transition out of rehabilitation programmes were discussed, and softening the transition by implementing sustainable structures for PA engagement was proposed to aid participants in the long term.

Perspectives

Among the main findings of the present literature review were the needs for individualized programmes and for sustainable social structures in securing long-term engagement in PA among people with T2DM. One potential way to accomplish this is to include sports clubs and other local activity providers in the rehabilitation approach.

Targeting inactive people in general, and not people with T2DM specifically, this has been practiced in Sweden as part of the *Physical Activity on Prescription* programme,⁶⁸ and a recent review has confirmed the positive effects of the programme on levels of PA.⁶⁹ However, the conceptualization of PA as a means to something else (e.g. lowered blood glucose), a view the present review cannot deny exemplifying to some extent, could be augmented by prescribing PA as medicine.⁷⁰ Contrarily, voluntarily driven sports clubs are likely populated by individuals perceiving PA in the given context as valuable in and of itself and it is unclear how these vastly different perspectives on PA mesh. Future research should seek to clarify not just how inclusion in voluntary sports communities affects

long-term PA among people with T2DM but also how this involvement is experienced and perceived by both programme participants and members of existing PA communities.

References

1. Chatterjee S, Khunti K, Davies MJ. Type 2 diabetes. *The Lancet*. 2017;389(10085):2239-2251. doi: 10.1016/S0140-6736(17)30058-2.
2. Sundhedsdatastyrelsen. Sygdomsforekomst - tabel.
<http://esundhed.dk/sundhedsregistre/uks/uks01/Sider/Tabel.aspx>. Updated 2018. Accessed November 11, 2018.
3. Jørgensen ME, Ellervik C, Ekholm O, Johansen NB, Carstensen B. Estimates of prediabetes and undiagnosed type 2 diabetes in denmark: The end of an epidemic or a diagnostic artefact? *Scand J Public Health*. 2018;Online.
4. Gæde P, Lund-Andersen H, Parving H, Pedersen O. Effect of a multifactorial intervention on mortality in type 2 diabetes. *N Engl J Med*. 2008;358(6):580-591. doi: 10.1056/NEJMoa0706245.
5. Fong D, Aiello L, Gardner T, et al. Retinopathy in diabetes. *Diabetes Care*. 2004;27(1). doi: 10.1007/978-1-4614-5441-0.
6. Tesfaye S. Neuropathy in diabetes. *Medicine*. 2015;43(1):26-32. doi: 10.1016/j.mpmed.2014.10.013.
7. DeFronzo M, Franz R, Keane M. Nephropathy in diabetes. *Diabetes Care*. 2004;27(1):S79-S83.
8. Shah AD, Langenberg C, Rapsomaniki E, et al. Type 2 diabetes and incidence of cardiovascular diseases: A cohort study in 1.9 million people. *The Lancet Diabetes and Endocrinology*. 2015;3(2):105-114. doi: 10.1016/S2213-8587(14)70219-0.
9. Sortsø C, Green A, Jensen PB, Emneus M. Societal costs of diabetes mellitus in denmark. *Diabetic Med*. 2016;33(7):877-885. doi: 10.1111/dme.12965.

10. Sortsø C, Emneus M, Green A, Jensen PB, Eriksson T. Societal costs of diabetes mellitus 2025 and 2040—Forecasts based on real world cost evidence and observed epidemiological trends in denmark. *Modern Economy*. 2015;6(10):1150-1166. doi: 10.4236/me.2015.610109.
11. Venables MC, Jeukendrup AE. Physical inactivity and obesity: Links with insulin resistance and type 2 diabetes mellitus. *Diabetes/metabolism research and reviews*. 2009;25(1):18-23. doi: 10.1002/dmrr.
12. Tuomilehto J., Indstrom J., Eriksson J., Valle T., Hamalainen E. & Uusitupa M. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344(18):1343-1350. doi: 10.1056/NEJM200105033441801.
13. Jeon CY, Lokken RP, Hu FB, Van Dam RM. Physical activity of moderate intensity and risk of type 2 diabetes: A systematic review. *Diabetes Care*. 2007;30(3):744-752. doi: 10.2337/dc06-1842.
14. Zanuso S, Jimenez A, Pugliese G, Corigliano G, Balducci S. Exercise for the management of type 2 diabetes: A review of the evidence. *Acta Diabetol*. 2010;47(1):15-22. doi: 10.1007/s00592-009-0126-3.
15. Biddle SJH, Fox K, Boutcher S. *Physical activity and psychological well-being*. Routledge; 2003.
16. Grigsby AB, Anderson RJ, Freedland KE, Clouse RE, Lustman PJ. Prevalence of anxiety in adults with diabetes. *J Psychosom Res*. 2002;53(6):1053-1060. doi: 10.1016/S0022-3999(02)00417-8.
17. Minet L, Møller S, Vach W, Wagner L, Henriksen JE. Mediating the effect of self-care management intervention in type 2 diabetes: A meta-analysis of 47 randomised controlled trials. *Patient Educ Couns*. 2010;80(1):29-41. doi: 10.1016/j.pec.2009.09.033.
18. Sundhedsstyrelsen. Patient education - a health technology assessment, summary. *Natl Board Heal Monit Heal Technol Assess*. 2009;11(3). doi:http://0-dx.doi.org.wam.leeds.ac.uk/10.1097/HPC.0b013e318177e00e. Updated 2009.

19. Sundhedsstyrelsen. National klinisk retningslinje for udvalgte sundhedsfaglige indsatser ved rehabilitering til patienter med type 2 diabetes.; 2015.
<https://www.sst.dk/da/udgivelser/2015/~media/CD075EE6B0144C6E806097921B63B98A.ashx>
20. Giles-Corti B, Donovan RJ. The relative influence of individual, social and physical environment determinants of physical activity. *Soc Sci Med*. 2002;54(12):1793-1812. doi: 10.1016/S0277-9536(01)00150-2.
21. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity. *Medicine & Science in Sports & Exercise*. 2000;32(5):963-975. doi: 10.1097/00005768-200005000-00014.
22. Ryan RM, Patrick H, Deci EL, Williams GC. Facilitating health behaviour change and its maintenance : Interventions based on self-determination theory. *The European Health Psychologist*. 2008;10:2-5. doi: 10.1080/17509840701827437.
23. Armitage CJ. Can the theory of planned behavior predict the maintenance of physical activity? *Health Psychology*. 2005;24(3):235-245. doi: 10.1037/0278-6133.24.3.235.
24. Rhodes R, de Bruijn G, Matheson DH. Habit in the physical activity domain: Integration with intention temporal stability and action control. *Journal of Sport and Exercise Psychology*. 2010;32(1):84-98. doi: 10.1123/jsep.32.1.84.
25. Aarts H, Paulussen T, Schaalma H. Physical exercise habit: On the conceptualization and formation of habitual health behaviors. *Health Educ Res*. 1997;12(3):363-374. doi: 10.1093/her/12.3.363.
26. Weinberg RS, Gould D. Exercise behavior and adherence. In: *Foundations of sport and exercise psychology*. 5.th ed. Human Kinetics; 2011:415-446.
27. Saltman RB, Figueras J. Analyzing the evidence on european health care reforms. *Health Aff*. 1998;17(2):85-108. doi: 10.1377/hlthaff.17.2.85.

28. NIH. Study quality assessment tools. U.S. Department of Health & Human Services. <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools?fbclid=IwAR27xVx2CUMov5hE0d4IKPBLlL3wj2Bp9AsQai0d9Q1gb5G7qu7Ug8HzQ1w>. Published 2018. Accessed November 18, 2018.
29. Caetano, Inês Rosendo Carvalho e Silva, Santiago LM, Marques M. Impact of written information on control and adherence in type 2 diabetes. *Revista da Associação Médica Brasileira*. 2018;64(2):140-147. doi: 10.1590/1806-9282.64.02.140.
30. Davies MJ, Heller S, Skinner TC, et al. Effectiveness of the diabetes education and self management for ongoing and newly diagnosed (DESMOND) programme for people with newly diagnosed type 2 diabetes: Cluster randomised controlled trial. *BMJ*. 2008;336(7642):491-495. doi: 10.1136/bmj.39474.922025.BE.
31. Karjalainen JJ, Kiviniemi AM, Hautala AJ, et al. Effects of exercise prescription on daily physical activity and maximal exercise capacity in coronary artery disease patients with and without type 2 diabetes. *Clinical Physiology and Functional Imaging*. 2012;32(6):445-454. doi: 10.1111/j.1475-097X.2012.01148.x.
32. Labrunée M, Antoine D, Vergès B, Robin I, Casillas J-, Gremeaux V. Effects of a home-based rehabilitation program in obese type 2 diabetics. *Annals of Physical and Rehabilitation Medicine*. 2012;55(6):415-429. doi: 10.1016/j.rehab.2012.06.001.
33. Martinus R, Corban R, Wackerhage H, Atkins S, Singh J. Effect of psychological intervention on exercise adherence in type 2 diabetic subjects. *Annals of the New York Academy of Sciences*. 2006;1084(1):350-360. doi: 10.1196/annals.1372.024.
34. Wisse W, Rookhuizen MB, de Kruif MD, et al. Prescription of physical activity is not sufficient to change sedentary behavior and improve glycemic control in type 2 diabetes patients. *Diabetes Research and Clinical Practice*. 2010;88(2):e10-e13. doi: 10.1016/j.diabres.2010.01.015.

35. Jansink R, Braspenning J, Keizer E, van der Weijden T, Elwyn G, Grol R. No identifiable Hb1Ac or lifestyle change after a comprehensive diabetes programme including motivational interviewing: A cluster randomised trial. *Scandinavian Journal of Primary Health Care*. 2013;31(2):119-127. doi: 10.3109/02813432.2013.797178.
36. Popay J, Roberts H, Sowden A, et al. *Guidance on the conduct of narrative synthesis in systematic reviews: A product from the ESRC methods programme*. Lancaster University; 2006. doi: 10.13140/2.1.1018.4643.
37. Malpass A, Andrews R, Turner KM. Patients with type 2 diabetes experiences of making multiple lifestyle changes: A qualitative study. *Patient Educ Couns*. 2009;74(2):258-263. doi: 10.1016/j.pec.2008.08.018.
38. Andrews R, Cooper AR, Montgomery AA, et al. Diet or diet plus physical activity versus usual care in patients with newly diagnosed type 2 diabetes: The early ACTID randomised controlled trial. *The Lancet*. 2011;378(9786):129-139. doi: 10.1016/s0140-6736(11)60442-X.
39. De Greef KP, Deforche BI, Ruige JB, et al. The effects of a pedometer-based behavioral modification program with telephone support on physical activity and sedentary behavior in type 2 diabetes patients. *Patient Educ Couns*. 2011;84(2):275-279. doi: 10.1016/j.pec.2010.07.010.
40. Van Dyck D, De Greef K, Deforche B, et al. Mediators of physical activity change in a behavioral modification program for type 2 diabetes patients. *International Journal of Behavioral Nutrition and Physical Activity*. 2011;8(1):105-18. doi: 10.1186/1479-5868-8-105.
41. Clark M, Hampson SE, Avery L, Simpson R. Effects of a tailored lifestyle self-management intervention in patients with type 2 diabetes. *British Journal of Health Psychology*. 2004;9(3):365-379. doi: 10.1348/1359107041557066.
42. Di Loreto C, Fanelli C, Lucidi P, et al. Validation of a counseling strategy to promote the adoption and the maintenance of physical activity by type 2 diabetic subjects. *Diabetes Care*. 2003;26(2):404-408. doi: 10.2337/diacare.26.2.404.

43. Kirk A, Mutrie N, MacIntyre P, Fisher M. Increasing physical activity in people with type 2 diabetes. *Diabetes Care*. 2003;26(4):1186-1192. doi: 10.2337/diacare.26.4.1186.
44. Kirk A, Mutrie N, MacIntyre P, Fisher M. Effects of a 12-month physical activity counselling intervention on glycaemic control and on the status of cardiovascular risk factors in people with type 2 diabetes. *Diabetologia*. 2004;47(5):821-832. doi: 10.1007/s00125-004-1396-5.
45. Kirk A, Mutrie N, MacIntyre PD, Fisher MB. Promoting and maintaining physical activity in people with type 2 diabetes. *Am J Prev Med*. 2004;27(4):289-296. doi: 10.1016/j.amepre.2004.07.009.
46. Kirk A, Barnett J, Leese G, Mutrie N. A randomized trial investigating the 12-month changes in physical activity and health outcomes following a physical activity consultation delivered by a person or in written form in type 2 diabetes: Time2Act. *Diabetic Med*. 2009;26(3):293-301. doi: 10.1111/j.1464-5491.2009.02675.x.
47. Döbler A, Herbeck Belnap B, Pollmann H, Farin E, Raspe H, Mittag O. Telephone-delivered lifestyle support with action planning and motivational interviewing techniques to improve rehabilitation outcomes. *Rehabilitation psychology*. 2018;63(2):170-181. doi: 10.1037/rep0000224.
48. Deakin TA, Cade JE, Williams R, Greenwood DC. Structured patient education: The diabetes X-PERT programme makes a difference. *Diabetic Med*. 2006;23(9):944-954. doi: 10.1111/j.1464-5491.2006.01906.x.
49. Cooper H, Booth K, Gill G. A trial of empowerment-based education in type 2 diabetes-global rather than glycaemic benefits. *Diabetes Res Clin Pract*. 2008;82(2):165-71. doi: 10.1016/S1557-0843(09)80006-7.
50. Kulzer B, Hermanns N, Reinecker H, Haak T. Effects of self-management training in type 2 diabetes: A randomized, prospective trial. *Diabetic Med*. 2007;24(4):415-423. doi: 10.1111/j.1464-5491.2007.02089.x.

51. Moreno E, Ochoa de Retana Garcia, Lourdes, Del Campo Pena, Maria Emma, et al. A pilot study to assess the feasibility of the spanish diabetes self-management program in the basque country. *Journal of diabetes research*. 2016;2016:10. doi: 10.1155/2016/9145673.
52. Rise M, Pellerud A, Rygg L, Steinsbekk A. Making and maintaining lifestyle changes after participating in group based type 2 diabetes self- management educations: A qualitative study. *Plos one*. 2013;8(5):80-97. doi: 10.1371/journal.pone.0064009.
53. Gram B, Christensen R, Christiansen C, Gram J. Effects of nordic walking and exercise in type 2 diabetes mellitus: A randomized controlled trial. *Clinical Journal of Sport Medicine*. 2010;20(5):355-361. doi: 10.1227/NEU.0b013e3181e56e0a.
54. Nicolucci A, Balducci S, Cardelli P, et al. Relationship of exercise volume to improvements of quality of life with supervised exercise training in patients with type 2 diabetes in a randomised controlled trial: The italian diabetes and exercise study (IDES). *Diabetologia*. 2012;55(3):579-588. doi: 10.1007/s00125-011-2425-9.
55. Praet SFE, Van Rooij, E. S. J., Wijtvliet A, et al. Brisk walking compared with an individualised medical fitness programme for patients with type 2 diabetes: A randomised controlled trial. *Diabetologia*. 2008;51(5):736-746. doi: 10.1007/s00125-008-0950-y.
56. Gallè F, Krakauer J, Krakauer N, Valerio G, Liguori G. Can an exercise-based educational and motivational intervention be durably effective in changing compliance to physical activity and anthropometric risk in people with type 2 diabetes? A follow-up study. *International journal of environmental research and public health*. 2019;16(5):701. doi: 10.3390/ijerph16050701.
57. Balducci S, D'Errico V, Haxhi J, et al. Effect of a behavioral intervention strategy on sustained change in physical activity and sedentary behavior in patients with type 2 diabetes. *JAMA : the journal of the American Medical Association*. 2019;321(9):880. doi: 10.1001/jama.2019.0922.
58. Vissenberg C, Nierkens V, Van Valkengoed I, et al. The impact of a social network based intervention on self-management behaviours among patients with type 2 diabetes living in

socioeconomically deprived neighbourhoods: A mixed methods approach. *Scand J Public Health*. 2017;45(6):569-583. doi: 10.1177/1403494817701565.

59. Thoolen BJ, Ridder DD, Bensing J, Gorter K, Rutten G. Beyond good intentions: The role of proactive coping in achieving sustained behavioural change in the context of diabetes management. *Psychology and Health*. 2009;24(3):237-254. doi: 10.1080/08870440701864504.

60. Lindenmeyer A, Whitlock S, Sturt J, Griffiths F. Patient engagement with a diabetes self-management intervention. *Chronic Illness*. 2010;6(4):306-316. doi: 10.1177/1742395310382798.

61. Maindal HT, Carlsen AH, Lauritzen T, Sandbaek A, Simmons RK. Effect of a participant-driven health education programme in primary care for people with hyperglycaemia detected by screening: 3-year results from the ready to act randomized controlled trial (nested within the ADDITION-denmark study). *Diabetic Med*. 2014;31(8):976-986. doi: 10.1111/dme.12440.

62. Puffelen AL, Rijken M, Heijmans, Monique J. W. M, Nijpels G, Schellevis FG. Effectiveness of a self-management support program for type 2 diabetes patients in the first years of illness: Results from a randomized controlled trial. *PLoS ONE*. 2019;14(6). doi: 10.1371/journal.pone.0218242.

63. Vissenberg C, Stronks K, Nijpels G, et al. Impact of a social network-based intervention promoting diabetes self-management in socioeconomically deprived patients: A qualitative evaluation of the intervention strategies. *BMJ Open*. 2016;6(4):e010254. doi: 10.1136/bmjopen-2015-010254.

64. van Dam HA, van Der Horst, Frans G., Knoop L, Ryckman RM, Crebolder, Harry F. J. M., van Den Borne, Bart H. W. Social support in diabetes: A systematic review of controlled intervention studies. *Patient Educ Couns*. 2005;59(1):1-12. doi: 10.1016/j.pec.2004.11.001.

65. Ryan RM, Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*. 2000;55(1):68-78. doi: 10.1037/0003-066X.55.1.68.

66. Orbell S, Verplanken B. The automatic component of habit in health behavior: Habit as cue-contingent automaticity. *Health Psychology*. 2010;29(4):374-383. doi: 10.1037/a0019596.

67. Michie S, Ashford S, Sniehotta FF, Dombrowski SU, Bishop A, French DP. A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: The CALO-RE taxonomy. *Psychology & health*. 2011;26(11):1479-1498. doi: 10.1080/08870446.2010.540664.

68. Statens folkhälsoinstitut. Individanpassad skriftlig ordination av fysisk aktivitet. 2011. <https://www.folkhalsomyndigheten.se/contentassets/c6e2c1cae187431c86c397ba1beff6f0/r-2011-30-far-individanpassad-skriftlig-ordination-av-fysisk-aktivitet.pdf>.

69. Onerup A, Arvidsson D, Blomqvist Å, et al. Physical activity on prescription in accordance with the swedish model increases physical activity: A systematic review. *Br J Sports Med*. 2018;Online fir(22):1-7. doi: 10.1136/bjsports-2018-099598.

70. Thing LF. En sociologisk diskussion af motion som behandling i velfærdsstaten. *Idrottsforum.Org*. 2005(2004):1-12.

Tables

Table 1: PubMed search protocol

Boolean operator	AND		
OR	Facet 1 – type 2 diabetics	Facet 2 – physical activity	Facet 3 – maintenance
	<u>MeSH terms:</u> [Diabetes mellitus, type 2]	<u>MeSH terms:</u> [Exercise], [Recreation], [Exercise therapy], [Recreation therapy], [Activities of daily living], [Dance therapy]	<u>MeSH terms:</u> [Guideline adherence], [Managed care programs], [Treatment adherence and compliance]
	<u>Text words:</u> [Type 2 diabetes], [DMT2], [T2DM]	<u>Text words:</u> [Training], [Workout], [Fitness], [Working out], [Physical inactivity]	<u>Text words:</u> [Maintain*], [Adher*], [Compliance], [Prolong*], [Sustain*], [Retention], [Retain*], [Continu*]

* indicates truncation.

Table 2: Characteristics and results of studies based on personalized counselling interventions

1. AUTHOR, YEAR & COUNTRY	STUDY DESIGN	N	AGE	% MEN	INTERVENTION DESCRIPTION	DURATION	ASSESSMENT	RESULTS
Malpass 2009 ³⁷ UNITED KINGDOM	Case study	30	NR	40	Control group: Standard dietary and exercise advice at baseline, 6 months and 12 months. Diet group: Received diet leaflets and goal-oriented motivational interviewing, and negotiated individual goals with dietitian at baseline, 3, 6, 9 and 12 months. Nurses reinforced advice and goals during nine appointments throughout the intervention. Diet + PA group: Received the same dietary intervention, were equipped with pedometers, motivating literature, pages for recording daily PA, and were asked to do 5 x 30 minutes of brisk walking per week in addition to normal activities. In this group, nurse appointments regarded both diet and PA.	12 months	- 6-9 M	<ul style="list-style-type: none"> - Participants in diet group or diet + PA group both experienced improvements in lifestyle regarding PA. - Participants in the diet + PA group used PA strategically to lower blood glucose. - Overall, combining diet and PA was perceived as helpful rather than counterproductive as a broader perspective helped participants take responsibility for their health and increased their confidence in the ability to manage T2DM. - Participants lacking social support could prefer mastering one change at a time, and in those cases, focus should first be on PA as PA is more often associated with increased motivation for additional changes.
Andrews 2011 ³⁸ UNITED KINGDOM	RCT	593	60	64.7	The intervention was the same as in Malpass 2009 (above) but with other participants and other outcome measures.	12 months	<ul style="list-style-type: none"> - Baseline - 6 M - 12 M Group effect Group effect 	Accelerometer (moderate to vigorous exercise, min/day): <ul style="list-style-type: none"> - Control: 26 (20), diet grp: 26 (20), diet + PA grp: 23 (17) - Control: 24 (20), diet grp: 29 (24), diet + PA grp: 33 (21) - Control: 26 (23), diet grp: 27 (24), diet + PA grp: 31 (25) - Diet/control: 6 M →, 12 M → - Diet + PA/control: 6 M ↑ $d_2 = 0.43$, 12 M ↑ $d_2 = 0.20$

De Greef 2011 ³⁹ Van Dyck 2011 ⁴⁰ BELGIUM	RCT	92	62	69	An initial 30-minute individual meeting between participant and a psychologist. Together, they developed an individualized lifestyle plan for behaviour change. Participants were given pedometers and a diary to track PA and received a total of 7 supportive phone calls the following 24 weeks. Calls regarded goal-setting, self-monitoring, self-efficacy, benefits of change, decisional balance, problem-solving strategies, social support and relapse prevention.	24 weeks	<ul style="list-style-type: none"> - Baseline - 6 M - 12 M Time x group 	<p>Pedometer (steps/day):</p> <ul style="list-style-type: none"> - Control: 5139 (2933), intervention grp: 4959 (2414) - Control: 3883 (2537), intervention grp: 7703 (2729) - Control: 3864 (3440), intervention grp: 6831 (3164) - $\Delta\text{INT}/\Delta\text{Control}$: 6 M $\uparrow d_4 = 1.52$, 12 M $\uparrow d_4 = 1.07$ <p>Accelerometer (light to vigorous exercise, min/day):</p> <ul style="list-style-type: none"> - Control: 322 (109), intervention grp: 300 (90) - Control: 306 (102), intervention grp: 323 (87) - Control: 273 (107), intervention grp: 311 (88) - $\Delta\text{INT}/\Delta\text{Control}$: 6 M $\uparrow d_4 = 0.41$, 12 M $\uparrow d_4 = 0.63$ <ul style="list-style-type: none"> - In addition to increases in PA, the intervention aided PA self-efficacy, coping with relapse and social support from family. All were mediating factors for self-reported PA. - Coping with relapse tended to be more closely related to PA at 6 months, while self-efficacy and social support were more closely related to PA at 12 months.
Clark 2004 ⁴¹ UNITED KINGDOM	RCT	100	59.5	58	An initial meeting with an interventionist to develop a personalized programme with a dietary goal, a PA goal, strategies to overcome barriers, and a contract, all based on the participant's current lifestyle. Motivation for change was developed through motivational interviewing. Short follow-up phone calls were made at 1,3 and 7 weeks. The whole process was repeated twice, starting at 12 and 24 weeks, respectively, with meetings designed to review progress. Achieved goals were replaced with new ones and	31 weeks	<ul style="list-style-type: none"> - Baseline - 12 M Time effect 	<p>Physical Activity Scale for the Elderly - Questionnaire:</p> <ul style="list-style-type: none"> - Intervention grp: 254.30 (95.23) - Intervention grp: 281.35 (114.84) - 12 M/baseline: \rightarrow <p>Summary of Diabetes Self-Care Activities – Exercise (days of adhering to recommendations per week):</p> <ul style="list-style-type: none"> - Intervention grp: 2.37 (1.21) - Intervention grp: 3.24 (1.47)

unsuccessful coping elicited new problem-solving strategies.
Participants received informative brochures at various times.

Time effect - **12 M**/baseline: $\uparrow d_1 = 0.65$

Di Loreto 2003 ⁴² ITALY	RCT	340	61.8	47	A physician saw all participants (control and intervention) for a clinical examination and counselling session on diet and PA. In addition, the intervention group received 30 min of PA counselling on motivation, self-efficacy, pleasure, support, comprehension, overcoming impediments and using a PA diary. Participants received a follow-up phone call after 1 month and an appointment in the outpatient diabetes clinic every three months to discuss progress, obstacles, etc.	24 months	Modifiable Activity Questionnaire (Metabolic equivalents hours/week):
						- Δ 24 M	- Control: 3.2 (8.8), intervention grp: 26.0 (27.0)
						Time x group	- Δ INT/ Δ Control: 24 M $\uparrow d_3 = 1.10$
							- % of participants above 10 metabolic equivalents h/week:
							o Intervention grp: Baseline 2.8 %, 24 M 69 %
							o Control: Baseline 3.8 %, 24 M 18 %
Kirk 2003 ⁴³ 2004a ⁴⁴ 2004b ⁴⁵ UNITED KINGDOM	RCT	70	57.6	50	All participants (control and intervention) received a standard exercise leaflet. A trained research assistant saw all intervention group participants for a 30-min session at baseline to encourage PA. Consultations regarded current PA, benefits, barriers, costs of becoming more active, suitable activities, social support, goal setting, and relapse prevention. These topics were discussed again at 1 and 3 months, using follow-up phone calls. Starting at 6 months, the process was repeated with a new consultation on relapse prevention and long-term maintenance, and follow-up phone calls at 7 and 9 months. 6M data were based on the initial 3-month intervention.	9 months	Accelerometer (counts/week):
						- Δ 6 M	- Control: -333343 (1702706), INT grp: 805576 (1781185)
						- Δ 12 M	- Control: -669061 (1702706), INT grp: 416632 (1772763)
						Time x group	- Δ INT/ Δ Control: 6 M $\uparrow d_3 = 0.65$, 12 M $\uparrow d_3 = 0.62$
							7-day physical activity recall (min/week):
						- Δ 6 M	- Control: -20.2 (62.9), intervention grp: 70.3 (177.6)
						- Δ 12 M	- Control: -13.7 (51.1), intervention grp: 55.2 (152.4)
						Time x group	- Δ INT/ Δ Control: 6 M $\uparrow d_3 = 0.67$, 12 M $\uparrow d_3 = 0.60$
							- % of participants met recommendations for PA:
							o INT: Baseline 20 %, 12 M 57 %
							o Control: Baseline 29 %, 12 M 10 %
Kirk 2009 ⁴⁶	RCT	134	61.3	48.2	Two distinct interventions based on either personal exercise consultation or written exercise consultation. The written	9 months	Pedometer (steps/day):
						- Baseline	- Control: 6000 (2000), intervention grp: 6600 (2700)

					intervention is described in table 5. The personal consultation intervention was almost the same as Kirk 2003; 2004a; 2004b (above) but with other participants.		<ul style="list-style-type: none"> - 6 M - 12 M Time x group 	<ul style="list-style-type: none"> - Control: 5800 (1800), intervention grp: 6500 (2800) - Control: 5200 (2100), intervention grp: 6300 (3000) - $\Delta INT/\Delta Control$: 6 M →, 12 M →
								Accelerometer (counts/week in thousands):
							<ul style="list-style-type: none"> - Baseline - 6 M - 12 M Time x group 	<ul style="list-style-type: none"> - Control: 1453 (435), intervention grp: 1548 (697) - Control: 1436 (450), intervention grp: 1571 (704) - Control: 1248 (500), intervention grp: 1404 (817) - $\Delta INT/\Delta Control$: 6 M →, 12 M →
	RCT	199	52	70	Participants in both the control and intervention groups received a 3-week <i>standard care</i> programme. Immediately hereafter, participants in the intervention group received a face-to-face session with motivational interviewing and action and coping planning regarding certain lifestyle areas determined to be most important for each participant. Afterwards, they received monthly telephone counselling for 12 months, addressing emotional distress and discussing their personal action plans. For some, target lifestyle areas changed during the study, but at least 92 % of participants focused on exercise at some point. Participants in the control group received written information on diet and PA at 3 and 9 months.	12 months		Exercise index: Self-reported score on a scale of 1-4 (<i>lower scores better</i>):
							<ul style="list-style-type: none"> - Δ 12 M Time x group 	<ul style="list-style-type: none"> - Control: -0.27 (1.9), intervention grp: -1.24 (2.0) - $\Delta INT/\Delta Control$: 12 M ↑ $d_3 = -0.50$

PA refers to physical activity. *Group effect* refers to effect of intervention based on between groups comparison. *Time effect* refers to effect of intervention based on within group comparison. *Time x group* refers to effect of intervention based on time-group-interaction data. Δ refers to absolute difference between baseline and post measurements. ↑ indicates a significant increase in PA. → indicates no significant difference. d_x refers to a Cohen's d-type effect size calculated as explained in "Data synthesis". *INT* refers to an intervention group. Values of outcomes are presented as mean (SD) unless otherwise stated. Qualitative results are presented as short descriptions of main findings.

Table 3: Characteristics and results of studies based on generalized teaching interventions

1. AUTHOR, YEAR & COUNTRY	STUDY DESIGN	N	AGE	% MEN	INTERVENTION DESCRIPTION	DURATION	ASSESSMENT	RESULTS
Deakin 2006⁴⁸ UNITED KINGDOM	RCT	314	61.5	52	Participants attended the X-PERT programme, consisting of six weekly two-hour sessions held in community venues. A diabetes research dietitian delivered the intervention with topics such as diet, prevention of complications, weight management through exercise, and goal setting, all aimed to empower participants through development of skills and confidence.	6 weeks	- Baseline - 14 M Group effect	Summary of Diabetes Self-Care Activities – Exercise (days of adhering to recommendations per week): - Control: 1.4 (2.5), intervention grp: 1.8 (2.3) - Control: 1.7 (2.7), intervention grp: 2.6 (2.4) - INT/control: 14 M ↑ $d_2 = 0.35$
Cooper 2008⁴⁹ UNITED KINGDOM	RCT	89	59	56	Educational intervention led by trained diabetes nurses, consisting of eight weekly group sessions, each lasting approximately two hours. Content included information about the disease, exercise, relaxation, self-management principles and exploration of diabetes-related feelings.	8 weeks	Time x group	Summary of Diabetes Self-Care Activities – Exercise - $\Delta INT/\Delta Control$: 6 M →, 12 M →
Kulzer 2007⁵⁰ GERMANY	Non-control trial	181	55.6	50.3	Treatment A: Didactic-oriented intervention focused on knowledge, skills and information about correct treatment, consisting of four 90-min group lessons. Treatment B: Group empowerment intervention focusing on cognitive and motivational processes of behaviour change during twelve 90-min sessions. Treatment C: Individual/group-based empowerment intervention similar to treatment B, but with half of the sessions conducted in an individual setting. Trained psychologists conducted all three interventions.	3 months	- Baseline - 15 M Time effect	Frequency of PA (score 0-4): - Treatment A: 1.0 (0.9), B: 0.8 (1.0), C: 0.9 (1.0) - Treatment A: 1.1 (0.9), B: 1.4 (1.0), C: 1.3 (1.0) - 15 M /baseline: o Treatment A: → o Treatment B: ↑ $d_1 = 0.6$ o Treatment C: ↑ $d_1 = 0.4$
Moreno 2016⁵¹	Non-control trial	171	63.4	52	Educational group sessions based on the theory of self-efficacy. Across six weeks, six 2.5-hour sessions on topics such as performance mastery, modelling, symptom interpretation, social persuasion, problem solving,	6 weeks	- Baseline	7-day physical activity recall (Metabolic equivalents hours/week): - Intervention grp: 5.5 (7.7)

SPAIN					decision making and resource utilization were completed. Two certified leaders, one of whom was a person with T2DM or a caregiver, led the sessions, thus emphasizing peer learning. Additionally, sessions were supported by educational material (books, leaflets, CDs).		- 7,5 M Time effect	- Intervention grp: 5.5 (not reported) - 7.5 M /baseline: → % of participants met recommendation for PA: - INT: Baseline 58 %, 7.5 M 70 %
Rise 2013 ⁵²	Case study	23	58	39	Three sessions of group education, lasting a total of 15 hours. Sessions were conducted weekly or fortnightly, were led by diabetes nurses with input from physicians, physiotherapists and experienced persons with T2DM, and included information about T2DM, PA and metabolic control. Sessions included lecturing, questions, interactive learning and group discussions.	3-6 weeks	- ~ 1 M - ~ 7 M	- Qualitative semi-structured interviews: - Factors influencing lifestyle change: Obtaining new knowledge, taking responsibility, receiving confirmation of healthy lifestyle. - Factors influencing maintenance of changes: Support, experiencing an effect, fear of complications, formation of new habits
NORWAY								
1. AUTHOR, YEAR & COUNTRY	STUDY DESIGN	N	AGE	% MEN	INTERVENTION DESCRIPTION	DURATION	ASSESSMENT	RESULTS
Gram 2010 ⁵³ DENMARK	RCT	68	60.6	54	Two distinct interventions based on PA supervised by a physiotherapist; one focusing on indoor fitness training, one focusing on outdoor brisk walking. In both interventions, activities were individually adapted. Interventions contained two weekly 45-min group sessions for the first two months and one weekly 45-min group session for the following two months. At the end of the interventions, participants were informed of training opportunities in	4 months	- 12 M	No significant changes in proportions of participants physically active >3 hours/week in either intervention group (self-reported). Numbers not available.

PA refers to physical activity. *Group effect* refers to effect of intervention based on between groups comparison. *Time effect* refers to effect of intervention based on within group comparison. *Time x group* refers to effect of intervention based on time-group-interaction data. Δ refers to absolute difference between baseline and post measurements. \uparrow indicates a significant increase in PA. \rightarrow indicates no significant difference. d_x refers to a Cohen's d-type effect size calculated as explained in "Data synthesis". *INT* refers to an intervention group. Values of outcomes are presented as mean (SD) unless otherwise stated. Qualitative results are presented as short descriptions of main findings.

Table 4: Characteristics and results of studies based on supervised exercise interventions

	their neighbourhood, and at 8 months, they were interviewed about PA.						
Nicolucci 2012 ⁵⁴ ITALY	RCT	606	NR	NR	Both the intervention group and control group received structured individual exercise counselling at baseline and every three months for the duration of the intervention. In addition, the intervention group received individualized and progressive aerobic and resistance training for a year, amounting to 150 min/week divided into two weekly sessions.	12 months - Δ 12 M Time x group - Δ 12 M Time x group	Short Form-36 questionnaire: Total volume of PA (Metabolic equivalents hours/week): - Control: 10.0 (8.7), INT grp: 20.0 (0.9) - Δ INT/ Δ Control: 12 M \uparrow $d_3 = 1.64$ Volume of non-supervised PA: - Control: 10.0 (8.7), INT grp: 12.4 (7.4) - Δ INT/ Δ Control: 12 M \uparrow $d_3 = 0.30$
Praet 2008 ⁵⁵ THE NETHERLANDS	Non-control trial	92	60	51	Two interventions; one based on brisk walking, and one based on medical fitness. Both interventions consisted of three weekly sessions of supervised exercise for a year, and both interventions had elements of endurance and resistance training. The brisk walking intervention was outside in groups of 15-25 with certified trainers and, for the first three months, a physical therapist. The medical fitness was supervised by a physical therapist, was more individual, and implemented weight machines and ergometer work.	12 months - 6 / 12 M - 6 / 12 M	Dropout rate during intervention: - Walking group: 6 M 45%, 12 M 63% - Fitness group: 6 M 30%, 12 M 56%
Gallé 2019 ⁵⁶ ITALY	Non-control trial	69	61.8	67.9	The intervention consisted of a motivational and educational group programme focusing on PA and diet. Sessions were biweekly and included topics such as PA benefits, home-based and outdoor training methods, barriers and problem solving. In addition, the programme contained supervised 1-hour group exercise sessions twice per week for the duration of the intervention.	9 months - Baseline - 9 M - 21 M Time effect Time effect	International Physical Activity Questionnaire – Short Form: Habitual PA (Metabolic equivalents min/week): - Intervention grp: 474.8 (90.3) - Intervention grp: 641.0 (53.5) - Intervention grp: 663.4 (57.0) - 9 M /baseline: \uparrow $d_1 = 2.24^*$ - 21 M /baseline: \uparrow $d_1 = 2.50^*$
Balducci 2019 ⁵⁷	RCT	300	61.7	61.3	Participants in the intervention group received an initial individual counselling session with a diabetologist, followed by 8 biweekly individual	25 months (sessions in	Accelerometer (Metabolic equivalents hours/week):

sessions of supervised exercise and counselling, with a certified exercise specialist, per year for 3 years. The intervention sought to gradually reduce sedentary time and increase light-, moderate-, and vigorous-intensity PA.	month 1, 13, 25)	-	Δ 12 M	-	Control: 0.4 (2.5), INT grp: 2.9 (2.8)
		-	Δ 24 M	-	Control: 0.0 (4.1), INT grp: 2.3 (3.8)
		-	Δ 36 M	-	Control: -1.0 (4.7), INT grp: 1.3 (4.4)
		Time x group		-	Δ INT/ Δ Control: 12 M \uparrow $d_3 = 0.94$, 24 M \uparrow $d_3 = 0.59$, 36 M \uparrow $d_3 = 0.51$

PA refers to physical activity. *Time effect* refers to effect of intervention based on within group comparison. *Time x group* refers to effect of intervention based on time-group-interaction data. Δ refers to absolute difference between baseline and post measurements. \uparrow indicates a significant increase in PA. d_x refers to a Cohen's d-type effect size calculated as explained in "Data synthesis". *INT* refers to an intervention group. Values of outcomes are presented as mean (SD) unless otherwise stated. *Effect size probably positively skewed as 17 of 69 participants dropped out and analysis was not intention-to-treat.

Table 5: Characteristics and results of studies on interventions combining personalized counselling and generalized teaching

1. AUTHOR, YEAR & COUNTRY	STUDY DESIGN	N	AGE	% MEN	INTERVENTION DESCRIPTION	DURATION	ASSESSMENT	RESULTS
Vissenberg 2017⁵⁸ THE NETHERLANDS	Case study	131	61.7	51.2	24 group sessions for participants with T2DM, 6 group sessions for their significant others (spouses, friends, etc.), and two therapy sessions with both the participant and a significant other present. The sessions covered topics such as disease, diet and exercise, and the topics were explored through discussions, group games and exercises, role-playing, action planning, etc. Significant others were included to provide social support during and after intervention participation.	10 months	<ul style="list-style-type: none"> - Baseline - 10 M - 16 M Time effect - 10 M 	<p>Summary of Diabetes Self-Care Activities – Exercise (days of adhering to recommendations per week):</p> <ul style="list-style-type: none"> - Intervention grp: 3.78 (NR) - Intervention grp: 4.83 (NR) - Intervention grp: 4.43 (NR) - 10 M/baseline: ↑ (data for effect size not available), 16 M/baseline: → - 27 qualitative interviews were conducted after the 10 month intervention and findings indicated an increase in overall PA in the intervention group, in accordance with the quantitative results.
Thoolen 2009⁵⁹ THE NETHERLANDS	RCT	180	61.9	58.9	Two individual sessions and four group sessions during a 12-week period. In the first individual session, participants discussed their experiences with T2DM, and in the group sessions they worked on personally relevant goals regarding PA, diet and medication, using a proactive 5-step plan for goal setting. In the final individual session, participants evaluated progress and made plans for the future. Trained diabetes nurses led all sessions.	12 weeks	<ul style="list-style-type: none"> - Baseline - 12 M Time effect - Baseline - 12 M Time effect 	<p>Summary of Diabetes Self-Care Activities – Exercise:</p> <ul style="list-style-type: none"> - Intervention grp: 3.2 (2.0) - Intervention grp: 4.1 (1.8) - 12 M/baseline: ↑ $d_1 = 0.48$ <p>Physical Activity Scale for the Elderly – Questionnaire:</p> <ul style="list-style-type: none"> - Intervention grp: 125 (60) - Intervention grp: 152 (76) - 12 M/baseline: ↑ $d_1 = 0.39$
Lindenmeyer 2010⁶⁰	Case study	22	61	59	The intervention consisted of five components, 1; Two-day training by health professionals to deliver the programme, 2;	12 weeks	<ul style="list-style-type: none"> - 6 M 	<ul style="list-style-type: none"> - Qualitative interviews with participants in the Diabetes Manual programme and controls revealed

UNITED KINGDOM					a workbook for participants with T2DM containing information and exercises regarding diet and PA, 3; a relaxation CD, 4; a frequently asked questions and programme overview CD for participants with T2DM and carers, and 5; telephone support at 1, 5 and 11 weeks. Some interviewees had completed the intervention, while some had not yet started.			marginally different behaviour between the groups.
								<ul style="list-style-type: none"> - There was a tendency that intervention participants more frequently used blood glucose self-testing. Additionally, several intervention participants mentioned a link between self-testing and PA and thus used PA to lower blood glucose. - No apparent effect of nurse telephone support on PA.
Maindal 2014 ⁶¹	RCT	509	62	53	An individual baseline interview about the participant's motivation, needs and readiness to change, followed by eight group sessions regarding motivation, informed decision-making, action experience and social involvement, led by nurses, dietitians, physiotherapists and general practitioners. At 12 weeks, the intervention was concluded with an individual interview with a nurse giving feedback in relation to individual goals, motivation and further actions.	12 weeks		International Physical Activity short-form Questionnaire: Volume of PA (Metabolic equivalents hours/week)
DENMARK							<ul style="list-style-type: none"> - 36 M - Group effect 	<ul style="list-style-type: none"> - Control: 44.99 (NR), intervention grp: 49.89 (NR) - INT/control: 36 M →
Kirk 2009 ⁴⁶	RCT	134	61.3	48.2	Two distinct interventions based on either personal exercise consultation or written exercise consultation. The personal intervention is described in table 2. Participants in the written consultation intervention received written PA material at baseline and 6 months and were encouraged to work through it. At baseline, topics included types of PA, health benefits, identifying and overcoming barriers, opportunities for PA, social support, preventing relapse, and developing goals. Based on progress, at 6 months participants received material to either strengthen current behaviour or to reinforce the information given at baseline.	9 months		Pedometer (steps/day):
UNITED KINGDOM							<ul style="list-style-type: none"> - Baseline - 6 M - 12 M - Time x group 	<ul style="list-style-type: none"> - Control: 6000 (2000), intervention grp: 5500 (2300) - Control: 5800 (1800), intervention grp: 5300 (2300) - Control: 5200 (2100), intervention grp: 5000 (2200) - ΔINT/ΔControl: 6 M →, 12 M →
								Accelerometer (counts/week in thousands):
							<ul style="list-style-type: none"> - Baseline - 6 M - 12 M - Time x group 	<ul style="list-style-type: none"> - Control: 1453 (435), intervention grp: 1282 (666) - Control: 1436 (450), intervention grp: 1234 (619) - Control: 1248 (500), intervention grp: 1130 (562) - ΔINT/ΔControl: 6 M →, 12 M →

Follow-up phone calls were made at 1, 3, 7 and 9 months.

RCT	168	63.6	55.4	Participants in the control group received a single educational lecture regarding treatment options and potential complications. In the intervention group, participants received a workbook and a group based support programme consisting of 3 sessions at 0, 1 and 2 months, regarding illness perceptions, goal setting, action plans and ways of support. At 5 months, participants met and reflected on their progress. Two trained nurses led all sessions, and participants in both the intervention group and the control group were encouraged to bring their partner or a close friend or relative to their respective sessions.	5 months		Summary of Diabetes Self-Care Activities – Exercise:
						- Baseline	- Intervention grp: 4.5 (1.8)
						- 8 M	- Intervention grp: 4.4 (1.7)
						Time effect	- 8 M /baseline: →

PA refers to physical activity. *Group effect* refers to effect of intervention based on between groups comparison. *Time effect* refers to effect of intervention based on within group comparison. *Time x group* refers to effect of intervention based on time-group-interaction data. Δ refers to absolute difference between baseline and post measurements. \uparrow indicates a significant increase in PA. \rightarrow indicates no significant difference. d_x refers to a Cohen's d-type effect size calculated as explained in "Data synthesis". *INT* refers to an intervention group. Values of outcomes are presented as mean (SD) unless otherwise stated. Qualitative results are presented as short descriptions of main findings.

Figure legends

Figure 1: Summary of the literature review process. The numbers in the parantheses refer to the first and second PubMed search processes, respectively. PA refers to physical activity.

Secondary search

Primary search

Exclusion

