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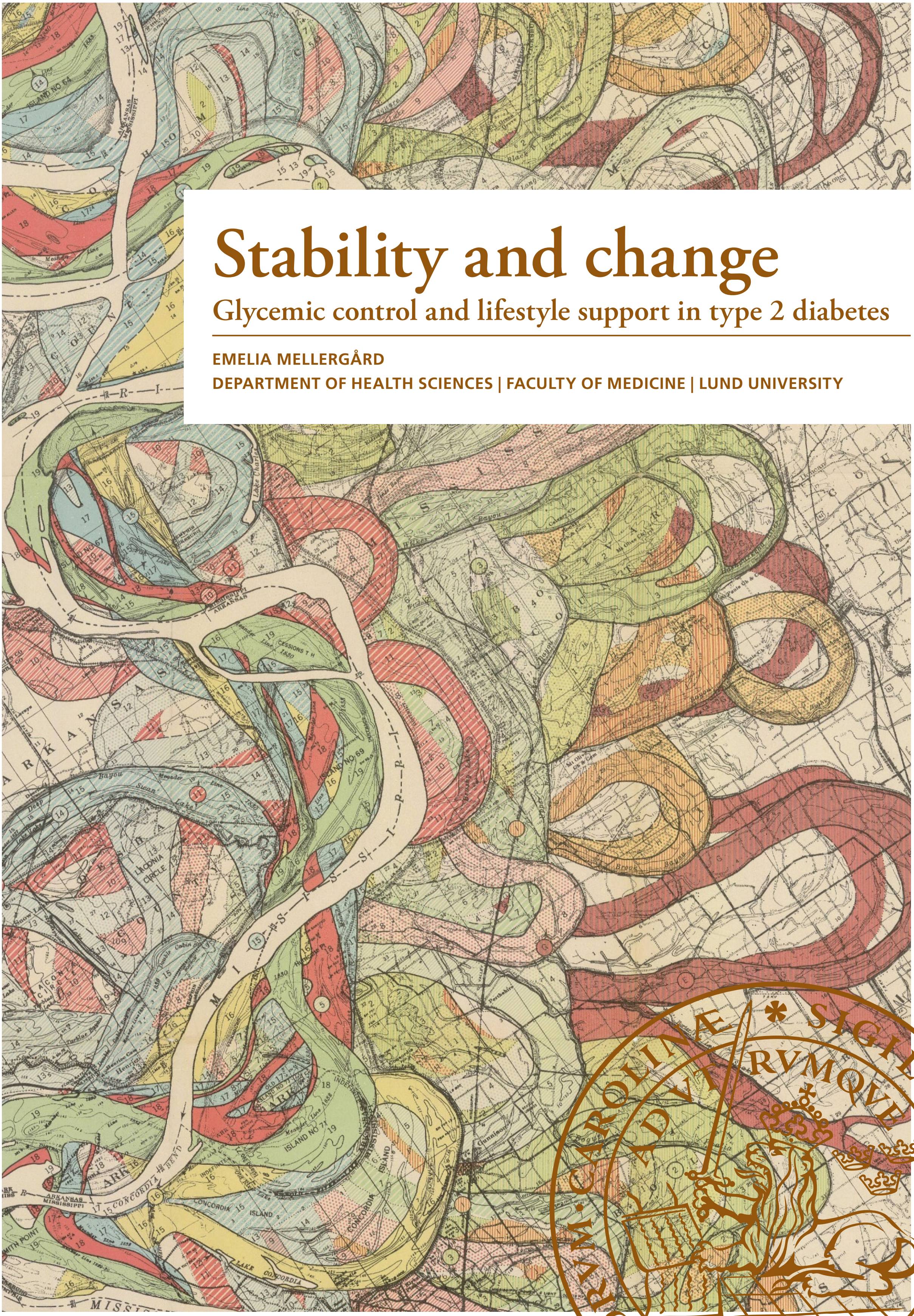

Stability and change

Glycemic control and lifestyle support in type 2 diabetes

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Glycemic control and lifestyle support in type 2 diabetes

Emelia Mellergård

DOCTORAL DISSERTATION
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Faculty opponent
Professor Gerhard Andersson
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Abstract

Type 2 diabetes is a serious, lifestyle-related condition characterized by insufficient glycemic control resulting in hyperglycemia. Long-term hyperglycemia is a major risk factor for a range of health complications, and type 2 diabetes complications are among the leading causes of morbidity and mortality worldwide. Of all forms of diabetes, type 2 diabetes constitutes around 90% of cases, indicating its impact on both an individual and a societal level. The management of type 2 diabetes is an everyday task, and the main responsibility for healthy glycemic control lies with the individual. Most individuals with type 2 diabetes, however, do not meet recommended treatment targets, implying a need for a better understanding of factors related to glycemic control, as well as for new, cost-effective solutions to support those with the disease. The overall aim of this thesis was to examine patient factors associated with glycemic control, and to develop and evaluate a web-based intervention to support diabetes self-management. Two prospective cohort studies (studies I and II) were conducted to examine the associations between sociodemographic and psychological factors, and glycemic control. A qualitative study utilizing semi-structured interviews (study III) was conducted to explore patients' needs and expectations regarding support for diabetes self-management, and views on the development of an intervention to support diabetes management. The effect of a new, web-based lifestyle tool for glycemic control in individuals with type 2 diabetes was investigated through a randomized controlled trial (study IV). The effect of the tool was further examined in a subgroup of insulin- resistant and obese individuals, and the cost-effectiveness of the tool was estimated. Results showed that men, individuals with obesity, and participants who reported a more negative appraisal of diabetes, had less stable glycemic control compared to other groups. Patients reported physical and emotional barriers to appropriate diabetes management, as well as a disconnect between their way of life and the lifestyle advice they received from health care professionals, and described a need for accessible and reliable support for diabetes self-management. Based on these results, a web-based lifestyle tool was developed and evaluated. Improved glycemic control was found in participants using the tool, compared to a waitlist control group. The response was further pronounced in a subgroup of insulin-resistant and obese individuals, and the tool was estimated to be cost-effective based on its potential ability to control risk factors for the disease. Men, individuals with obesity, and individuals with a more negative experience of type 2 diabetes may be at greater risk of developing future diabetes complications due to their attenuated glycemic variability. There is a need for personalized and autonomy-supportive interventions that can provide both encouragement and relevant information to the patient group, to support risk factor control. A new, web-based intervention supporting self-reflection and including a personal adaptation of health information can be used to support enhanced glycemic control in individuals with type 2 diabetes, and may be particularly effective in obese and insulin-resistant individuals.

Keywords: Type 2 diabetes; Glycemic control; HbA1c; Self-management; Psychological adjustment; Health psychology; Web-based interventions

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Preface

Jonas is 67 years old and was diagnosed with type 2 diabetes 3 years ago. He recalls the diagnosis putting a dampener on his spirit. He was already struggling with the fact that he was retiring that same year, which in itself was a difficult transition for him. He didn't know much about diabetes, but took some time to read about it and learnt that it is a serious health condition. Jonas is currently not bothered by having diabetes, although he does sometimes worry about future complications and, from time to time, feels depressed about it. He has basic knowledge about type 2 diabetes, but would like advice tailored to his needs and life situation. He has tried to increase his exercise by adding daily walks to his routine, but feels that he "falls off the wagon" too easily and is not motivated enough to keep new habits over time.

Vivianne has had type 2 diabetes for 8 years now. When she was diagnosed she considered diabetes as just another problem and did not feel concerned. For this reason, she did not consider lifestyle changes right away. Vivianne is overweight and has without success tried several ways of losing weight. She values close relationships and has good support from her family; she especially appreciates the support from her daughter. She feels embarrassed about having diabetes and would rather not talk to others about it. In health care settings, she often feels judged because of her overweight. Vivianne tends to feel either hopeless or very energetic in striving for her goals. She feels responsible for managing her diabetes, but often doubts her capability in this regard.

During my work on this thesis, I have met both "Jonas" and "Vivianne" and they have made me understand two things about having type 2 diabetes: First of all, everyone values good health, but for many, a preventive perspective on health does not come naturally. Secondly, advice about health and diabetes management needs to be adjusted to fit the patient, not only the diagnosis. The majority of patients with type 2 diabetes do not reach treatment target goals, which demonstrates a possible disconnect between treatment guidelines and the patients' reality. This thesis will hopefully highlight the importance of individualized care to support patients such as Jonas and Vivianne, and show through examples how this can be done.

Abstract

Type 2 diabetes is a serious, lifestyle-related condition characterized by insufficient glycemic control resulting in hyperglycemia. Long-term hyperglycemia is a major risk factor for a range of health complications, and type 2 diabetes complications are among the leading causes of morbidity and mortality worldwide. Of all forms of diabetes, type 2 diabetes constitutes around 90% of cases, indicating its impact on both an individual and a societal level. The management of type 2 diabetes is an everyday task, and the main responsibility for healthy glycemic control lies with the individual. Most individuals with type 2 diabetes, however, do not meet recommended treatment targets, implying a need for a better understanding of factors related to glycemic control, as well as for new, cost-effective solutions to support those with the disease. The overall aim of this thesis was to examine patient factors associated with glycemic control, and to develop and evaluate a web-based intervention to support diabetes self-management.

Two prospective cohort studies (studies I and II) were conducted to examine the associations between sociodemographic and psychological factors, and glycemic control. A qualitative study utilizing semi-structured interviews (study III) was conducted to explore patients' needs and expectations regarding support for diabetes self-management, and views on the development of an intervention to support diabetes management. The effect of a new, web-based lifestyle tool for glycemic control in individuals with type 2 diabetes was investigated through a randomized controlled trial (study IV). The effect of the tool was further examined in a subgroup of insulin- resistant and obese individuals, and the cost-effectiveness of the tool was estimated.

Results showed that men, individuals with obesity, and participants who reported a more negative appraisal of diabetes, had less stable glycemic control compared to other groups. Patients reported physical and emotional barriers to appropriate diabetes management, as well as a disconnect between their way of life and the lifestyle advice they received from health care professionals, and described a need for accessible and reliable support for diabetes self-management. Based on these results, a web-based lifestyle tool was developed and evaluated. Improved glycemic control was found in participants using the tool, compared to a waitlist control group. The response was further pronounced in a subgroup of insulin-resistant and obese individuals, and the tool was estimated to be cost-effective based on its potential ability to control risk factors for the disease.

Men, individuals with obesity, and individuals with a more negative experience of type 2 diabetes may be at greater risk of developing future diabetes complications due to their attenuated glycemic variability. There is a need for personalized and autonomy-supportive interventions that can provide both encouragement and relevant information to the patient group, to support risk factor control. A new, web-based intervention supporting self-reflection and including a personal adaptation of health information can be used to support enhanced glycemic control in individuals with type 2 diabetes, and may be particularly effective in obese and insulin-resistant individuals.

Popular science summary/ Populärvetenskaplig sammanfattning

Diabetes är samlingsnamnet för olika sjukdomstillstånd där kroppen har försämrad blodsockerkontroll. Traditionellt klassificeras diabetes i typ 1 diabetes, typ 2 diabetes, graviddiabetes, samt olika monogena former av diabetes. Av all diabetes utgörs 90% av typ 2 diabetes. Två sjukdomsprocesser utmärker typ 2 diabetes: relativ brist på insulinfrisättning och/eller insulinresistens. Båda dessa processer leder till kroniskt förhöjt blodglukos, s k hyperglykemi. När kroppen inte reglerar blodets glukoshalt tillräckligt väl behöver den hjälp, inte minst för att förhindra de skador som långvarigt högt blodsocker kan ge upphov till. Förhöjt blodglukos kan på sikt leda till både mikrovaskulära och makrovaskulära komplikationer, som t ex skador på ögats näthinna, hjärtkärlsjukdom, eller nedsatt känsel.

Typ 2 diabetes har både genetiska och livsstilsrelaterade orsaker. Risken att utveckla typ 2 diabetes ökar med stigande ålder, men övervikt är också en stark riskfaktor. Att antal fall av typ 2 diabetes ökar världen över brukar delvis härledas till vår förändrade livsstil, där vi idag i allt större utsträckning är fysiskt inaktiva och konsumerar energität kost. Behandling av typ 2 diabetes fokuserar därför i hög grad på livsstilsförändringar som viktnedgång, ökad fysisk aktivitet och kostförändringar. Målet med all diabetesbehandling är att uppnå och bibehålla en så hälsosam blodglukoskontroll som möjligt. Fysisk aktivitet gör t ex kroppens celler mer känsliga och bättre på att ta upp glukos, vilket leder till sänkt blodsocker. Diabetes kan upplevas som en krävande sjukdom att leva med, och typ 2 diabetes ställer stora krav på individen vad gäller egenvård i syfte att uppnå och bibehålla god blodsockerkontroll.

Det övergripande syftet med denna avhandling var att undersöka sambanden mellan olika patientfaktorer och blodsockerkontroll hos individer med typ 2 diabetes, att utforska patienters syn på egenvård och behov av stöd, samt att utvärdera ett nytt internetbaserat stöd för livsstilsförändring vid typ 2 diabetes.

I den första studien undersöktes sambanden mellan de sociodemografiska faktorerna kön, utbildningsnivå, civilstånd, ålder och BMI, och blodsockerkontroll över två års tid hos 158 individer med typ 2 diabetes. Blodsockerkontroll mättes som HbA1c och variabilitet i HbA1c, vilket speglar individens långsiktiga blodsocker och fluktuationer i blodsockret. Resultaten visade att män samt individer med ett BMI kännetecknande för fetma hade sämre glykemisk kontroll jämfört med kvinnor eller individer med normalvikt.

I den andra studien undersöktes relationen mellan de psykologiska faktorerna upplevd förmåga att hantera diabetes, sjukdomsupplevelse och motivation, och blodsockerkontroll över två års tid hos 158 individer med typ 2 diabetes. Resultaten visade att en mer negativ sjukdomsupplevelse var associerad med en försämrad blodsockerkontroll.

I den tredje studien intervjuades 22 individer med typ 2 diabetes om sina erfarenheter av diabetes och diabeteshantering, samt behov av ytterligare stöd. Intervjun innehöll bland annat frågor om upplevda hinder mot god diabeteshantering, tidigare försök att förändra sin livsstil, tilltro till sin egen förmåga att uppnå god blodsockerkontroll, samt personliga mål med sin diabeteshantering. Studiedeltagarna fick även testa olika motivations- och reflektionsfrämjande, datorbaserade övningar och ge återkoppling kring både innehåll och utformning av dessa. Syftet med övningarna var att få deltagarnas perspektiv på den här typen av övningar i relation till diabeteshantering, samt utforska om deltagarna tyckte att det var ett relevant fokus för att stödja egenvård vid diabetes. Resultaten visade att typ 2 diabetes kan upplevas som känslomässigt påfrestande, som kan bidra till att diabeteshanteringen upplevs som svår eller otillräcklig, men också att upplevelsen av typ 2 diabetes skiljer sig mycket åt mellan individer. Några beskrev svårigheter att genomföra livsstilsförändringar som de fått råd om från sjukvården, eftersom förändringarna passade dåligt in i den egna vardagen. Mer information om riskerna med typ 2 diabetes och om diabeteshantering, samt individanpassat stöd från sjukvården beskrevs som viktigt. Studiedeltagarna uppgav även olika sätt som ett internetbaserat stöd skulle kunna göras tillgängligt och relevant för dem, t ex genom regelbundna uppdateringar av innehållet och ett fokus på uppmuntran snarare än att komma med pekpinnar.

I den fjärde studien utvärderades ett internetbaserat verktyg för att stödja god egenvård vid typ 2 diabetes. Verktyget utformades med en bred teoretisk bas och med utgångspunkt i de resultat som framkommit i intervjustudien. Ett viktigt fokus för verktyget var att förmedla hälsorelaterad information och främja personlig reflektion, i syfte att förankra informationen hos individen och stimulera till personanpassade livsstilsförändringar. I studien jämfördes användare av verktyget med individer som ännu inte använde verktyget, och resultaten visade att de som använde verktyget förbättrade sin blodsockerkontroll. Denna förbättring var särskilt påtaglig hos en grupp av överviktiga och insulinresistenta diabetespatienter. En hälsoekonomisk analys av verktyget gjordes även, som visade att verktyget skulle kunna innebära en kostnadsbesparing jämfört med den vård som ges idag.

Sammantaget visar resultaten i denna avhandling att män, individer med fetma och personer med en mer negativ upplevelse av typ 2 diabetes har sämre blodsockerkontroll jämfört med andra grupper. Ett nytt internetbaserat livsstilsverktyg som uppmuntrar självreflektion och en personlig anpassning av hälsoinformation kan användas för att stödja förbättrad blodsockerkontroll hos personer med typ 2 diabetes och är särskilt effektivt för överviktiga och insulinresistenta individer.

List of papers

I Mellergård E, Johnsson P, Eek F, 2020. Sociodemographic factors associated with HbA1c variability in type 2 diabetes: A prospective exploratory cohort study. BMC Endocrine Disorders 20, 102.

II Mellergård E, Johnsson P, Eek F, 2021. Effects of perceived competence, negative appraisal, and motivation orientation on glycemic stability in individuals with type 2 diabetes: A prospective cohort study. Primary Care Diabetes 15, 269–274.

III Mellergård E, Johnsson P, Eek F, 2021. Developing a web-based support using self-affirmation to motivate lifestyle changes in type 2 diabetes: A qualitative study assessing patient perspectives on self-management and views on a digital lifestyle intervention. Internet Interventions 24, 100384.

IV Dwibedi C, Mellergård E, Cuba Gyllensten A, Nilsson K, Axelsson A, Bäckman M, Sahlgren M, Friend SH, Persson S, Franzén S, Abrahamsson B, Steen Carlsson K, Rosengren A, 2021. Effect of self-managed lifestyle treatment in patients with type 2 diabetes. Unpublished manuscript, last modified August 10th, 2021.

Abbreviations

ACT	Acceptance and Commitment Therapy
ADA	American Diabetes Association
ADS	Appraisal of Diabetes Scale
ANDIS	All New Diabetics in Scania (cohort)
ANOVA	(univariate) analysis of variance
BCT	behavior change technique
BMI	body mass index
CI	confidence interval
CRC	Clinical Research Centre
CV	coefficient of variation
FPG	fasting plasma glucose
HbA1c	glycated hemoglobin
IFG	impaired fasting glucose
IGT	impaired glucose tolerance
IHE	Institute for Health Economics
MI	motivational interviewing
MOD	mild obesity-related diabetes
NICE	National Institute for Health and Care Excellence
OGTT	oral glucose tolerance test
PCDS	Perceived Competence for Diabetes Scale
QALY	quality-adjusted life-year
RCT	randomized controlled trial
SD	standard deviation
SDT	self-determination theory

SEP	socioeconomic position
T1D	type 1 diabetes
T2D	type 2 diabetes
TSRQ	Treatment Self-Regulation Questionnaire
WHO	World Health Organization

Introduction

Diabetes is a serious condition, or rather a number of conditions, occurring when blood glucose levels rise above normal. It is traditionally classified into type 1 diabetes (T1D), type 2 diabetes (T2D), gestational diabetes mellitus, and diabetes due to other causes, e.g., rare monogenic forms of the disease. Since clinical presentation and disease progression may vary considerably, the classification is far from straightforward and misdiagnosis is common (ADA, 2020). However, diabetes in all its forms is a consequence of inadequate glucose control, due to an inability to produce, or effectively use, insulin. Insulin, a hormone produced in the pancreas, allows glucose from the bloodstream to enter the body's cells where it can be converted into energy (IDF, 2019). Symptoms of diabetes can be vague and difficult to interpret, often leading to prolonged detection. Raised blood glucose levels over time are associated with an increased risk of both acute and long-term health consequences, described in greater detail further on.

Type 1 diabetes

In T1D, an autoimmune reaction spurs the body's immune system to attack the insulin-producing β-cells of the pancreas, resulting in a reduction in, or complete cessation of, production of insulin (IDF, 2019). The loss of β-cells is noticeable at the onset of diagnosis, although in adults the process can be slow. The causes of the autoimmune reaction are not yet fully understood, but it is likely triggered by both genetic and environmental determinants. Individuals of all ages can develop T1D, and symptoms include excessive thirst, fatigue, sudden weight loss, frequent urination, and vision changes (Agardh et al., 2005; IDF, 2019). The treatment of T1D involves insulin therapy for metabolic optimization, combined with a diet and exercise regimen to keep glycemic levels stable.

Type 2 diabetes

Type 2 diabetes accounts for almost 90% of all cases of diabetes (Saedi et al., 2019). It is characterized by sustained hyperglycemia, i.e., elevated levels of glucose that circulate in blood plasma. In normal cases, raised levels of blood glucose promote secretion of insulin from pancreatic β-cells, which stimulates glycogen production in the liver and glucose uptake in tissue cells. Both glycogen and glucose uptake in tissue cells reduce blood glucose levels (Figure 1) (Inzucchini et al., 2012).

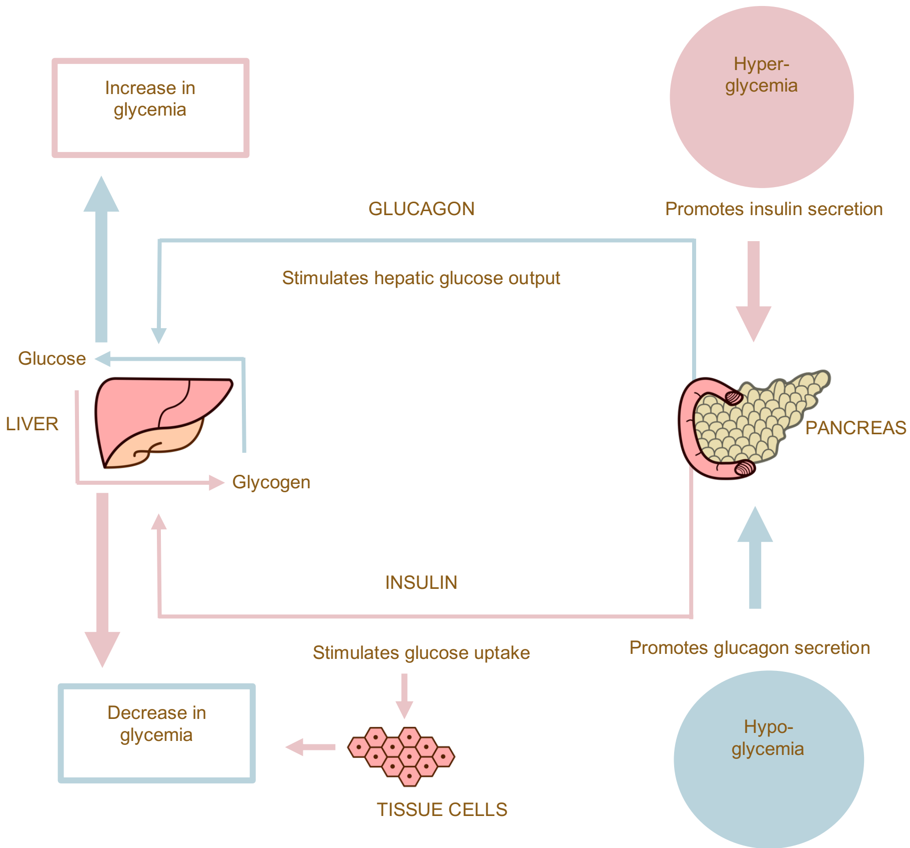

Figure 1 When blood glucose levels are above normal, the pancreas releases insulin, which lowers glucose in the bloodstream by stimulating muscle glucose uptake or storage of glucose in fat and liver cells. When glucose levels fall below the normal range, the pancreas promotes glucagon secretion, which transfers glucose out of liver and fat cells to raise blood glucose.

In T2D, sustained hyperglycemia is a result of both insulin resistance and insulin deficiency, leading to increased blood glucose levels over time. The clinical presentation is similar in T1D and T2D, although it is commonly less dramatic in T2D. Symptoms of hyperglycemia vary and can be difficult to detect, prolonging diagnosis. For this reason, T2D can remain undetected for several years (IDF, 2019). However, early diagnosis is important, since life expectancy is reduced by 5–10 years in individuals with T2D, compared to the general population (Lind et al., 2021).

Diagnosis

Distinguishing between T1D and T2D can be difficult, as not all individuals with T1D show features of an autoimmune-mediated disorder, and as obesity is a growing problem in both childhood and adulthood (Atkinson et al., 2014). A diagnosis of diabetes is based on fasting plasma glucose (FPG) concentrations, blood glucose concentrations, glycated hemoglobin concentrations, or abnormal results of an oral glucose tolerance test (OGTT) (DiMeglio et al., 2018). A summary of the diagnostic criteria provided by the World Health Organization (WHO) can be found in Table 1. Fasting plasma glucose is tested to determine if hyperglycemia is present even with no glucose intake. An OGTT can be used to test whether blood glucose is significantly raised following a glucose challenge. Plasma glucose levels can be measured to provide a more instant picture of glycemia. Measures of glycated hemoglobin (HbA1c) are utilized to determine average glycemic control over the past months (ADA, 2020; Kovatchev, 2017).

Table 1 Diagnostic criteria for diabetes

Diabetes can be diagnosed based on any of the following WHO criteria:
FPG ≥7 mmol/L
OGTT with FPG ≥7 mmol/L and/or 2-hour plasma glucose ≥11.1 mmol/L
HbA1c ≥48 mmol/mol
Random plasma glucose ≥11.1 mmol/L in the presence of diabetes symptoms

FPG = fasting plasma glucose; HbA1c = glycated hemoglobin; OGTT = oral glucose tolerance test; WHO = World Health Orginazation.

Prevalence

Diabetes is one of the fastest growing diseases of the current century, and it has been estimated that it will affect up to 700 million individuals in less than 25 years from now. The increase in prevalence is mainly due to population growth, aging, urbanization, and increasing prevalence of obesity and physical inactivity (Wild et al., 2004). Today, 463 million adults worldwide aged 20–79 years are living with diabetes (IDF, 2019). The majority of them live in low- or middle-income countries (WHO, 2016). The global prevalence of diabetes increases with age, and is slightly higher in men than in women (Figure 2) (Saeedi et al., 2019). Although prevalence of diabetes is lower in Scandinavia compared to other parts of Europe, it has been rising since the 1990s. In Sweden, the total prevalence of diabetes has been predicted to rise from 7% in 2013 to 10% by 2050 (Andersson et al., 2015).

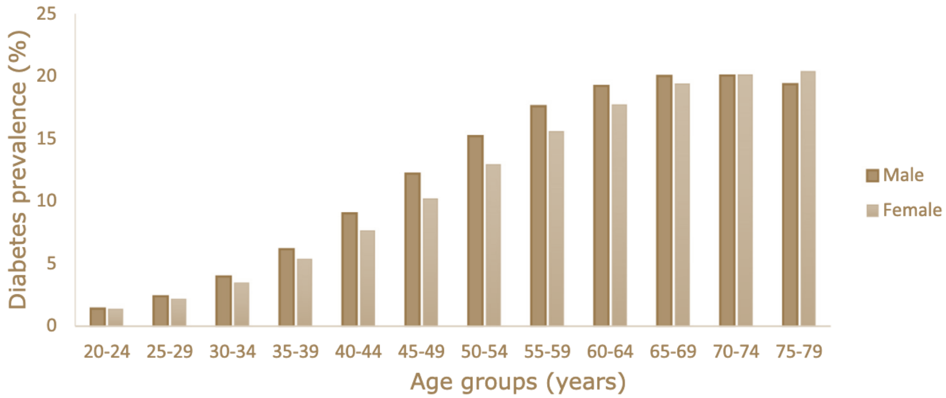

Figure 2 Global prevalence of diabetes, 2019**.** Reprinted from Saeedi et al. (2019). Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation, *Diabetes Research and Clinical Practice*, Vol 157, p 5. Copyright 2019, with permission from Elsevier.

Pathophysiology

The pathophysiology of T2D is highly heterogeneous, affecting the glucose homeostasis through different processes (Skyler et al., 2017; Pearson, 2019). Two concurrent conditions are at the center of T2D pathophysiology, namely, insulin resistance and relative insulin deficiency (Agardh et al., 2005). Both conditions eventually lead to hyperglycemia, one of the main pathophysiological factors at play in T2D (Chatterjee et al., 2017). In the presence of hyperglycemia, the body's insulin production at first increases and compensates for insulin resistance, but eventually cannot keep up and begins to fall behind the body's demands (Peyrot, 1999). Impaired glucose tolerance (IGT) and impaired fasting glucose (IFG) are conditions where blood glucose levels are raised above normal, though below the diagnostic threshold. Both IGT and IFG signal a risk for future development of T2D (IDF, 2019). The progression from normal glucose tolerance, to IGT and IFG, and eventually to T2D, takes several years (Weyer et al., 1999).

Risk factors

Type 2 diabetes most likely results from a combination of genetic predisposition and environmental triggers (IDF, 2019). However, the increasing prevalence of diabetes outpaces genetic variation, suggesting that environmental or lifestyle-dependent factors are key drivers in diabetes progression (Skyler et al., 2017). Risk factors for T2D include energy-dense diet, decreased physical activity, increased sitting, stress, depression, and a low socioeconomic position (SEP). One of the primary risk factors for T2D is increased body mass index (BMI), which is evident in populations worldwide (Kolb & Martin, 2017). A related risk factor for developing T2D is SEP, where low levels of socioeconomic determinants (e.g., educational level, income, occupation) are associated with a 40–60% higher relative risk compared to high levels (Kolb & Martin, 2017). Changes in socioeconomic status primarily affect two areas of importance for diabetes development: dietary habits and physical activity. Lack of physical activity and overweight are to some extent consequences of an increasingly Westernized lifestyle (sometimes referred to as "Coca-colonization", indicating a greater intake of refined sugars/starch and saturated fat), and are both strongly associated with increased risk of developing T2D (Agardh et al., 2005; Zimmet, 2001). Low physical activity is associated with a 40% higher relative risk compared to high physical activity, and a diet characterized by red and processed meat, refined grains, high-fat dairy, eggs, and fried products is associated with a 44% higher relative risk (Smith et al., 2016; Jannasch et al., 2017). In conclusion, where accompanied by healthier lifestyle habits, higher SEP may lower the risk of T2D (Kolb & Martin, 2017).

Consequences

Over time, hyperglycemia causes different complications, both microvascular and macrovascular. Microvascular complications include retinopathy, nephropathy, and neuropathy, while macrovascular complications include coronary artery disease, peripheral arterial disease, and stroke. Individuals with diabetes have a twofold increased risk of vascular diseases (Sarwar et al., 2010). The incidence of many diabetic complications is directly associated with the degree of hyperglycemia, indicating that improving glycemic control can reduce these outcomes (Holman et al., 2008). In other words, controlling hyperglycemia is a key focus in minimizing the detrimental effects of T2D. Significant hyperglycemia is present years before diagnosis, suggesting that the risk of complications commences long before the onset of clinical diabetes (Peyrot, 1999).

The amount spent on diabetes treatment and treatment of complications due to diabetes is significant, with health care expenditures being five times higher for individuals with diabetes, compared to individuals without (Björk, 2001). Apart from hospital-based care, there is also a substantial cost related to absence from work due to T2D (Andersson et al., 2020). Early diagnosis and improved treatment are therefore important also from a health economic perspective.

Glycemic control

"Glycemic control" refers to keeping blood glucose levels within normal ranges (Figure 3). Glycemia is a dynamic process, characterized by momentary fluctuations. These fluctuations occur in an intricate hormonal network, operating as a sort of shock absorber to different challenges, e.g., in the form of food intake and physical activity. Glucose homeostasis is also sensitive to psychosocial stress, since it may complicate the execution of behavioral routines necessary for glycemic control (Peyrot, 1999). The attributes of these challenges, along with the capacity of the metabolic system to handle them, establish the quality of glycemic control (Kovatchev, 2017). Target levels for glycemic control are individual, but a general aim stated by the National Institute for Health and Care Excellence (NICE) is 48–53 mmol/mol (NICE, 2015). Most individuals with diabetes do not reach their target HbA1c goals (Edelman & Polonsky, 2017).

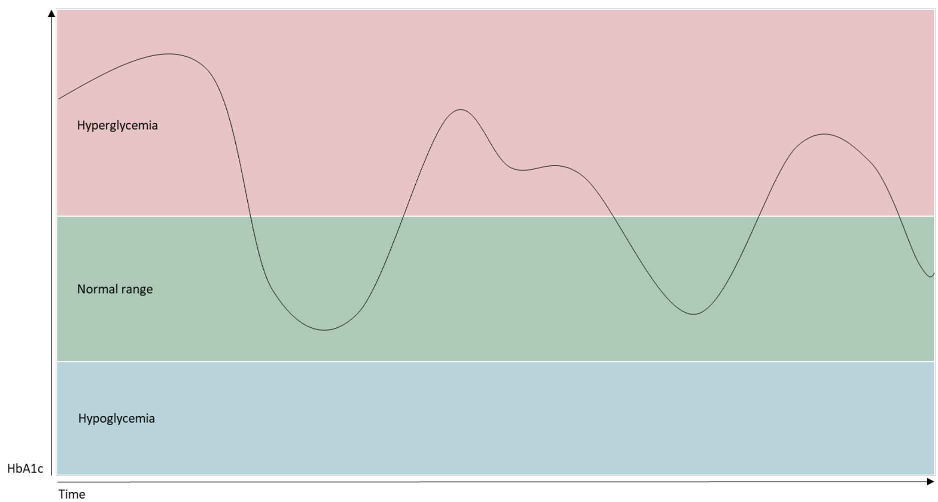

Figure 3 Glycemic control. Appropriate glycemic control is considered to keep glycated hemoglobin (HbA1c) within a normal range, avoiding both hyperglycemia and hypoglycemia.

Measures

The variation in blood glucose over time can be captured by different measures of glycemic control. Average glycemia is determined by measuring glycated hemoglobin, HbA1c, which measures blood glucose concentrations over a time period of 8–12 weeks. HbA1c is the benchmark for long-term glycemic control, due to its predictive value for diabetes complications (Higgins, 2012). It is measured in mmol/mol or expressed as percentage, which denotes the amount of glucose attached to hemoglobin in the red blood cells (Figure 4). Plasma glucose measurements give information about current concentration of glucose in the blood, and are given in mmol/L.

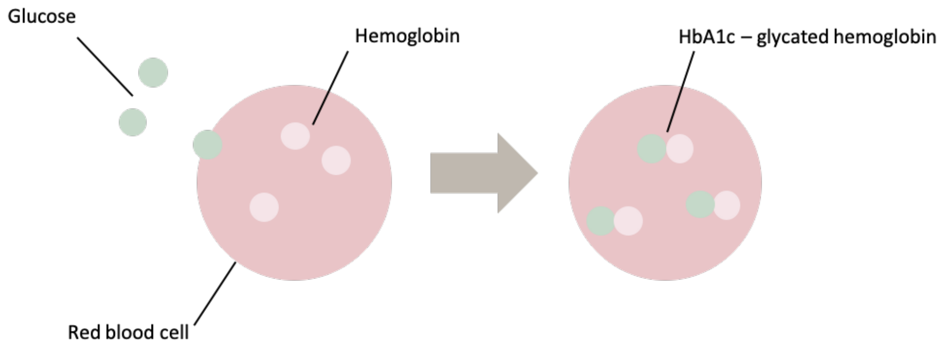

Figure 4 Glycated hemoglobin (HbA1c).

Glycemic variability

Glycemic variability has emerged as an additional measure of glycemic control, and may be a better predictor of diabetes complications than average glycemic measures (Gorst et al., 2015). "Glycemic variability" refers to glucose variations over a set period of time. Short-term variability encompasses within-day and between-day fluctuations, whereas long-term glycemic variability is based on measurements over several weeks or months, usually involving HbA1c (Ceriello et al., 2018; Gorst et al., 2015). Raised HbA1c variability in T2D is associated with mortality, cardiovascular disease, renal disease, nephropathy, and symptoms of depression (Ceriello et al., 2018; Skriver et al., 2015; Gorst et al., 2015; Ravona-Springer et al., 2017; Noyes et al., 2017). There is no "gold standard metric" for measuring HbA1c variability, although it is most commonly expressed as the standard deviation (SD) or coefficient of variation (CV) of HbA1c (Noyes et al., 2017).

Diabetes care

Prevention

There is good evidence that T2D is preventable by lifestyle changes. Several large studies over the last decades have shown that lifestyle interventions can prevent T2D, and that programs aimed at stimulating lifestyle changes can be more effective at reducing blood glucose levels than standard drug treatment (Tuomilehto et al., 2001; DPP, 2002; Uusitupa et al., 2019). The goal of preventive interventions is always to decrease insulin resistance, which can be done through increased physical activity and dietary changes, as a means to weight control. Individuals at risk for diabetes should be offered structured lifestyle support aiming at weight reduction, since reduced weight lowers glycemia (Agardh et al., 2005). Weight reduction can be achieved in different ways, and the support needs to be individualized and based on both patient preferences and clinical judgment. Lifestyle interventions that include 150 min/week of physical activity, as well as a diet-induced weight loss of 5–7%, have been shown to reduce the risk of T2D by 58% (Tuomilehto et al., 2001; DPP, 2002). However, distinguishing the effects of weight loss on glycemic control from other factors is often difficult, since weight loss almost always is simultaneous with changes in physical activity and/or dietary changes (Uusitupa et al., 2019).

Treatment

The main goals of T2D treatment are to prevent complications and maintain quality of life (Davies et al., 2018). Today, support for lifestyle changes is the cornerstone of all diabetes treatment, mainly with a focus on diet and physical activity to achieve glycemic control, since near normal glucose levels have been shown to dramatically decrease the risk of future complications due to diabetes (Peyrot, 1999). Physical activity has a positive effect on insulin sensitivity, by enhancing the ability for glucose uptake in tissue but not affecting the insulin level in circulating blood. Diet recommendations are increasingly being individualized, rather than giving focused advice about an ideal macronutrient composition for diabetes management (Ley et al., 2014). However, most patients are unable to maintain increased physical activity and/or dietary changes over time, and then treatment needs to be complemented with a glucose-lowering drug such as metformin. Metformin improves insulin sensitivity and is the first-line medicine when drug treatment of hyperglycemia is indicated (Bailey, 2017).

Self-management of diabetes

Self-management of diabetes includes various activities, such as regularly checking blood glucose levels, keeping to a diet, exercising, and adhering to medication recommendations. Individuals who are supported to implement and sustain these complex self-management skills, as well as overcoming barriers to them, have better outcomes (Hu et al., 2011; Chatterjee et al., 2018).

From adherence to autonomy

Emphasis on control and adherence rather than supporting patient independence can be a problem in diabetes care (Fisher et al., 2017). Health care professionals are traditionally trained to treat acute illnesses, and socialized to accept the responsibility to solve their patients' problems. They feel effective when they come up with solutions to patients' problems, and frustrated when they cannot. When working with diabetes, health care professionals may feel a responsibility to get their patients to achieve optimal glycemic control, in order to prevent the health complications of inadequate glucose control. However, when they fail to control their patients' behavior, they may be frustrated, and project this onto the patients by labeling them "non-compliant" (Snoek & Skinner, 2010).

However, the reality is that in the course of a year, a person with T2D will visit a nurse or general practitioner once or twice (Sabale et al., 2015). The person needs to manage the diabetes independently for the rest of the year. Hence, diabetes management is an ongoing task that predominantly involves self-management behaviors on the part of the patient, not health care professionals. Over recent decades, diabetes education has shifted from an emphasis on knowledge, compliance, and skills in the late 1970s, to an approach centred on self-management, autonomy, and empowerment (Hermanns et al., 2020). The latter has proven to be more effective regarding glycemic control and promoting collaboration in order to help the patient make informed decisions about his or her diabetes management (Snoek & Skinner, 2010).

The empowerment process involves efforts to identify one's problem, assess the roots of the problem, envision a change towards something better, and develop strategies to overcome possible barriers on the way. Through this process, the individual develops new beliefs about his or her ability to influence his or her situation (Wallerstein & Bernstein, 1988). Patients are empowered when they have the knowledge, skills, attitudes, and self-awareness that they need to change their behavior in order to improve their quality of life (Funnel et al., 1991). The knowledge needed to manage diabetes can be categorized into two domains. The first domain includes knowledge about diabetes and treatment options, which enables the patient to make judgements about various self-management options. The second domain is support towards self-awareness about the patients' own values, needs, goals, and aspirations regarding diabetes management (Snoek & Skinner, 2010).

Empowerment emphasizes a biopsychosocial model of disease and illness, which is different from the compliance-oriented model described above. With this approach, changing habits or one's lifestyle is considered much more elaborate than gaining knowledge about facts or acquiring new skills. Understanding how patients think and feel about their diabetes, how their social and environmental context is structured, and what biological factors may influence their ability to cope with having a chronic illness, is central to properly supporting the self-management of diabetes (Young-Hyman et al., 2016).

Barriers

Difficulties in achieving good glycemic control need to be acknowledged and addressed, in order for diabetes self-management to be successful (Ahola & Groop, 2012). Barriers to adequate diabetes management can be considered from three different levels: a personal, an interpersonal, and an environmental level (Polonsky, 1999). On a personal level, thoughts, feelings, and attitudes towards diabetes management can act as barriers to adequate diabetes control. Depression, stress, health beliefs, diabetes distress, fear, or unrealistic expectations can make it difficult to both know what to do, and properly engage in behaviors beneficial to one's health. On an interpersonal level, relationships may influence different aspects of diabetes management. Conflicts with spouses or other family members, insufficient (or too much) support from others, or lack of good relations with health care professionals can make self-management of diabetes more difficult to sustain. Environmental factors include stress, work conditions, and other external influences that may affect the prerequisites for good diabetes management.

Self-management support

Self-management support needs to be based on patient-perceived problems. An illustrative example is that of an arthritis education program focusing on preventing disability, and disability management. On its own, it is a reasonable effort, since disability is a key area of concern in arthritis. However, the main issue for patients with arthritis is pain. Supporting self-management of arthritis should therefore primarily focus on pain management (Lorig & Holman, 2003).

So what should support for self-management of diabetes focus on? This question is raised in study III. A traditional answer would be "optimizing glycemic control," yet this may not be the first priority for diabetes patients (Strowig, 1982). In general, patients may need help to identify and explore problems related to diabetes management, as well as support to explore feelings and beliefs regarding diabetes or other relevant issues. They may further need support to identify personal goals and behavior changes that will lead to these goals, and make some form of commitment to change and plan to take action (Snoek & Skinner, 2010). Lorig & Holman (2003) have identified five core skills in diabetes self-management: problem solving, decision making, resource utilization, forming of a patient-health care provider partnership, and taking action. Problem solving includes defining the problem, generating solutions, solution implementation, and evaluation. Having the information needed to make day-to-day decisions in response to changes in one's condition is at the center of decision making. Resource utilization includes knowing how to use available resources, e.g., the internet. To form a patient-health care provider partnership, the patient needs to be able to discuss choices about treatment, make informed choices, and accurately report any changes relating to his or her condition. Taking action includes making action plans and carrying them out.

The thinking on self-management and its effects on health status has, to a large degree, focused on the assumption that changed behaviors can improve health outcomes, largely based on epidemiological studies linking current behaviors to future health problems (Lorig & Holman, 2003). There are, however, other factors influencing diabetes management that need to be considered to understand and support effective self-management. Some of these will be described in the following section.

Psychological aspects of living with diabetes

Psychological adjustment to chronic illness is of great importance and can only be achieved through efforts to adjust to the new life circumstances that it brings (de Ridder et al., 2008). Previous research has demonstrated that individuals with diabetes experience increased levels of non-specific emotional distress and have higher likelihood of having anxiety disorders (Young-Hyman et al., 2016; Smith et al., 2013). Moreover, the prevalence of depression is nearly twice as high in individuals with T2D compared to those without (Roy & Lloyd, 2012). Reduced psychological well-being may affect adjustment to diabetes in different ways: by affecting overall quality of life negatively, by reducing physical activity level, or by impairing the patient's ability to communicate effectively with health care providers (Chew et al., 2017; Snoek & Skinner, 2006). Adjustment to diabetes is important, and often involves managing beliefs about the cause of the illness ("Why did it happen?"), as well as beliefs about whether or not the illness can be controlled ("What can I do to manage it?"). Although behavioral aspects remain the primary target of clinical intervention, the emotional experiences of living with diabetes are increasingly recognised (Fisher et al., 2019).

Diabetes distress

Previous research suggests that stress can adversely affect glycemic control, both through hormonal pathways and energy mobilization, and by disrupting the individual's self-care behaviors (Surwit et al., 1992; Peyrot et al., 1999; Pouwer et al., 2010). Individuals with diabetes must on a daily basis make numerous decisions regarding food, activity and medication (IDF, 2005). Since the ability to manage diabetes to a large extent depends on the individual, diabetes management can be perceived as stressful and as a burden to overall wellbeing. The term "diabetes distress" refers to psychological stress specific to living with diabetes (Perrin et al., 2017). It can include feeling overwhelmed by the demands of self-management, worry about future complications, feelings of guilt and shame, fears, and concerns about potential loss of functions or about access to care (Fisher et al., 2019). It is an expected response to having diabetes, rather than a sign of psychopathology, and the prevalence ranges from 18% to 35% in a general T2D population, but is higher in more vulnerable groups (Fisher et al., 2019; Mathiesen et al., 2018). Diabetes distress can influence self-management behaviors, with subsequent effects on glycemic control (Skinner et al., 2019; Rubin & Peyrot, 2001). Not surprisingly, poor glycemic control can also lead to increased distress (Snoek et al., 2015; Gonzalez et al., 2016). Interventions to address diabetes distress commonly aim at supporting the patient to recognize that "how you feel will affect what you do" (Fisher et al., 2019). Using autonomy-supportive, person-centred approaches is associated with reduced diabetes distress (Skinner et al., 2019).

Approaches to change

There are several models and theories on how different psychological factors might influence and change health behaviors. These either focus on specific factors (attitudes, control, self-efficacy, hardiness, resilience, optimism/pessimism, sense of coherence, personality, social support, social status, decision making, to mention a few), or they look at more complex associations involving several, interacting factors. These models aim to predict health behaviors/health outcomes through different pathways, e.g., through individual health beliefs (Andersson, 2018). Other theories and models focus on the motivational underpinnings of behavior change, where "motivation" is defined as the process that initiates, guides, and maintains goal-directed behavior (Lakerveld et al., 2020). The theoretical framework of this thesis is influenced by the approaches described below.

Biopsychosocial model of health

The biopsychosocial model of health is built on the premises that physical health and wellbeing are shaped by the interactions between biological, psychological, and social factors. It first emerged within the field of psychiatry, to address the dysfunctional relationship between the medical model and treatment of behavioral and psychological problems (Engel, 1977). In Engel's classic paper, he states:

> "The boundaries between health and disease, between well and sick, are far from clear and never will be clear, for they are diffused by cultural, social, and psychological considerations." (p. 132)

The biopsychosocial model includes both the patient and the illness, evaluating all factors contributing to both illness and patienthood, rather than giving primacy to biological factors alone. Today, there is accumulated evidence for the contribution of social, psychological, and biological factors to several health outcomes (Suls & Rothman, 2004). In diabetes, the biopsychosocial model would seem particularly fitting, since diabetes impacts on physical, social, and psychological aspects of life across cultures (Nicolucci et al., 2013). A previous study explored biopsychosocial characteristics of patients with insufficient glycemic control to determine whether distinct biopsychosocial profiles could be identified in this group (Elissen et al., 2017). Although the study was cross-sectional and could not determine which patient characteristics are the strongest predictors of glycemic control, the results indicated that insufficient glycemic control is associated with a generally worse biopsychosocial profile, including lower income and education levels, longer diabetes duration, and lower levels of self-efficacy.

Lifestyle and behavioral factors contribute to the development and progression of diabetes, and factors such as stress and psychological comorbidity have been identified as associated with poorer treatment outcomes (Gonzalez et al., 2007; Peyrot et al., 1999). In a position statement of the American Diabetes Association (ADA), the integration of psychosocial factors with medical care was endorsed, in recognition of the fact that medical management of diabetes requires the engagement of the patient, who is the key player for implementation of a treatment regimen (Young-Hyman et al., 2016).

Self-determination theory

Self-determination theory (SDT) is concerned with motivation, and especially different types of motivation (Deci & Ryan, 2008; Lakerveld et al., 2020). At the core of SDT are three central phenomena: the need for autonomy, the need for competence, and the need for relatedness. "Autonomy" refers to a form of functioning associated with volition and self-regulation ("taking interest"), "competence" concerns the need to feel efficacious and having a sense of mastery ("seeking challenges"), and "relatedness" is the need to feel socially connected to others ("striving for connection"). These three phenomena are considered as basic needs of all humans, essential not only for motivation but also for well-being (Ryan & Deci, 2017).

Self-determination theory differentiates between autonomous and controlled motivation. "Autonomy" or 'autonomous motivation" refers to intrinsically motivated behavior characterized by a sense of choice and congruency between a person's behavior and values (e.g., "I ride my bicycle to work because I think it's better for the environment"), while "controlled motivation", or extrinsically motivated behaviour, concerns behaviors that are instrumental for some consequence and can involve behaving in a certain way because of external demands or threats (e.g., "I ride my bicycle to work because my doctor told me I need daily exercise"). Externally motivated behavior is theorized to have a low likelihood of facilitating behavioral maintenance, while autonomy is believed to foster behaviors that are likely to last (Teixeira et al., 2012). Support for autonomy has in previous studies been shown to increase patient motivation and ability to regulate glucose levels, as well as help patients feel more competent (Macrodimitris et al., 2001; Williams et al., 1998; Teixeira et al., 2012; Williams et al., 2004).

"Perceived competence" refers to the feeling of being personally able to control important outcomes (Williams et al., 2005). In diabetes, "perceived competence" could refer to feeling able to maintain blood glucose values within a healthy range (Williams et al., 2004). In a clinical context, patients' perceived competence can be enhanced through health care professionals acknowledging their perspective, supporting their initiatives, offering different treatment choices, and providing relevant information while not exerting pressure or control over them (Lakerveld et al., 2020). Both autonomous and competence motivations are associated with improved diabetes self-management, as well as glycemic control (Shigaki et al., 2010; Trouilloud,& Regnier, 2013).

Self-affirmation theory

Self-affirmation theory is concerned with how we explain ourselves, and the world at large, to ourselves. These explanations have the purpose of maintaining a perceived adequacy and integrity of the self, sorting out any inconsistency, and any implications of such inconsistency for our view of ourselves. Hence, self-affirmation theory is about the coping processes that restore self-regard when it is threatened (Sherman, 2013). Receiving information about their health and need for lifestyle changes could pose a threat to patients' self-integrity, e.g., by raising doubts about the ability to self-manage diabetes. According to self-affirmation theory, the effect of this threat may be renegotiated by affirming central values, helping the individual to be more objective about self-threatening information and not resort to denial or rationalization (Steele, 1988; Cohen & Sherman, 2014). In this way, patients can be supported to see personal relevance in otherwise threatening health information. Affirming personal values has in previous research been found to decrease sedentary behavior, buffer stress responses, and influence health-promoting behaviors (Falk et al., 2015; Creswell et al., 2005; Epton & Harris, 2008; Cohen & Sherman, 2014).

Motivational interviewing

Motivational interviewing (MI) was first developed in clinical practice with the aim of enhancing patients' treatment motivation by helping them to be proactive participants in therapy and promoting their commitment to change. In therapy, situations are created where the patient can engage in self-exploration and contemplation of change, rather than directing the patient towards change or trying to impose motivation (Miller & Rollnick, 2013). Some of the core skills in MI are reflection, open questioning, and affirmation. Motivational interviewing is a patient-centered approach, and has in previous research been used as an autonomy-supportive element in interventions to support diabetes management (Mathiesen et al., 2018). It has been demonstrated to both affect dietary behavior and weight reduction (Ekong & Kavookijan, 2016; Lakerveld et al., 2020). Supporting autonomy is a mechanism of action proposed by both MI and SDT, and has in previous studies been shown to improve patients' glycemic control (Nouwen et al., 2011; Lakerveld et al., 2020). Use of MI is moreover associated with increased perceived competence and reduced diabetes distress (Skinner et al., 2019; Raaijmakers et al., 2014; Mathiesen et al., 2018).

Maintenance of behavior change

Although health behaviors can be effectively modified by interventions, there is limited evidence for how well behavior changes are sustained over time. In T2D, the continuous maintenance of behaviors is essential in order to not only achieve but also uphold lifestyle changes. In a comprehensive review of behavior change theories, by Kwasnicka et al. (2016), five overarching theoretical themes were generated, reflecting theoretical explanations about how behavior changes are maintained (Table 2).

Table 2 Themes relevant to behavior change maintenance, identified by Kwasnicka et al. (2016).

Theme	Brief theoretical explanation
Maintenance motives	People tend to maintain behaviors if the behavior is congruent with their identity, values, and beliefs, if they enjoy the behavior, or if they are satisfied with the outcomes of the behavior.
Self-regulation	People tend to maintain behavior if they successfully monitor and regulate the new behavior, and have strategies to overcome barriers to the performance of the new behavior.
Resources	People are better at maintaining behaviors if their psychological and physical resources are plentiful.
Habit	People are effective at maintaining behaviors which have become habitual and which are supported by automatic responses to relevant cues.
Environmental and social influences	People tend to maintain behaviors for which they have a supportive environment and social support from others.

Maintenance motives help establish priorities, and can act as a motor driving the initial behavior change. Expectations of outcomes may initially motivate a behavior change, which is more likely to be maintained if the behavior corresponds with the values and beliefs the individual holds. Individuals are hypothesized to engage more strongly if they have positive maintenance motives, reflecting a sense of volition and autonomy, not only motivation to avoid negative consequences.

Self-regulation refers to any effort made by the individual to actively control behavior and utilize goal-directed responses instead of automatic behaviors, in an effort to unlearn previous habits. It includes coping with barriers, and building skills (e.g., planning skills, inhibition control, self-monitoring, managing lapses) to more effectively self-regulate the own behavior.

Resources are psychological and physical assets that can be used to support the process of behavior change. In times of limited resources (e.g., due to stress), habitual behaviors are likely to dominate.

Habits are automated behaviors established over time and with repetition. Reinforcement is considered an important part of habit formation, enabling behavioral responses to be connected to situational stimuli. Repeated association of stimuli and response leads to maintenance of the new behavior. Habitual behaviors require minimal awareness and resources.

Environmental and social influences refers to the contexts in which a behavior is being adopted and maintained. A supportive environment and positive social influences are believed to facilitate behavior change maintenance, by providing an incentive structure for behavioral options. Social encouragement and help can increase the individual's capacity to maintain a behavior.

Web-based interventions

Definition and potential

The term "web-based intervention" is a broad umbrella term, including prevention, promotion, and education interventions operated through a website (Barak et al., 2009). These interventions are defined based on their key components: program content, multimedia use/choices, provision of interactive online activities, and provision of guidance and supportive feedback. Different subtypes of web-based interventions can be categorized based on these components: web-based education interventions, self-guided web-based therapeutic interventions, and human-supported web-based therapeutic interventions (Table 3).

Table 3 Sub-types of web-based interventions.

Web-based intervention subtype	Description
Web-based education interventions	Nonactive educational content, informative although relatively static (very few or no interactive activities), may provide partial support through generic automated feedback or through a moderated online forum.
Self-guided web-based therapeutic interventions	Content informed by theory and deliberately designed to support cognitive, behavioural, and emotional change. May provide some degree of automated and/or tailored feedback, e.g., after completing a self-assessment questionnaire.
Human-supported web-based therapeutic interventions	Content informed by theory and deliberately designed to support cognitive, behavioural, and emotional change. Incorporates a human to support, guide, and provide feedback, usually offered on a one-to-one basis, e.g., through email, chat function, or via webcam.

Web-based interventions have the advantage of reach and access, and possible cost-effectiveness, and can be tailored to fit individual preferences and needs (Cotter et al., 2014; Ritterband et al., 2009). They also have the potential to provide ongoing support over time, to circumvent the often fading short-term benefits that diabetes self-management efforts tend to have (Chatterjee et al., 2018; Pal et al., 2013).

A behavior change model for internet interventions has previously been described by Ritterband et al. (2009). The model includes nine focus areas through which internet interventions may produce behavior change and symptom improvement (Figure 5). Although not claiming to be exhaustive, the model gives an understanding of the complex interactions involved in the development of internet interventions designed to promote changed behavior.

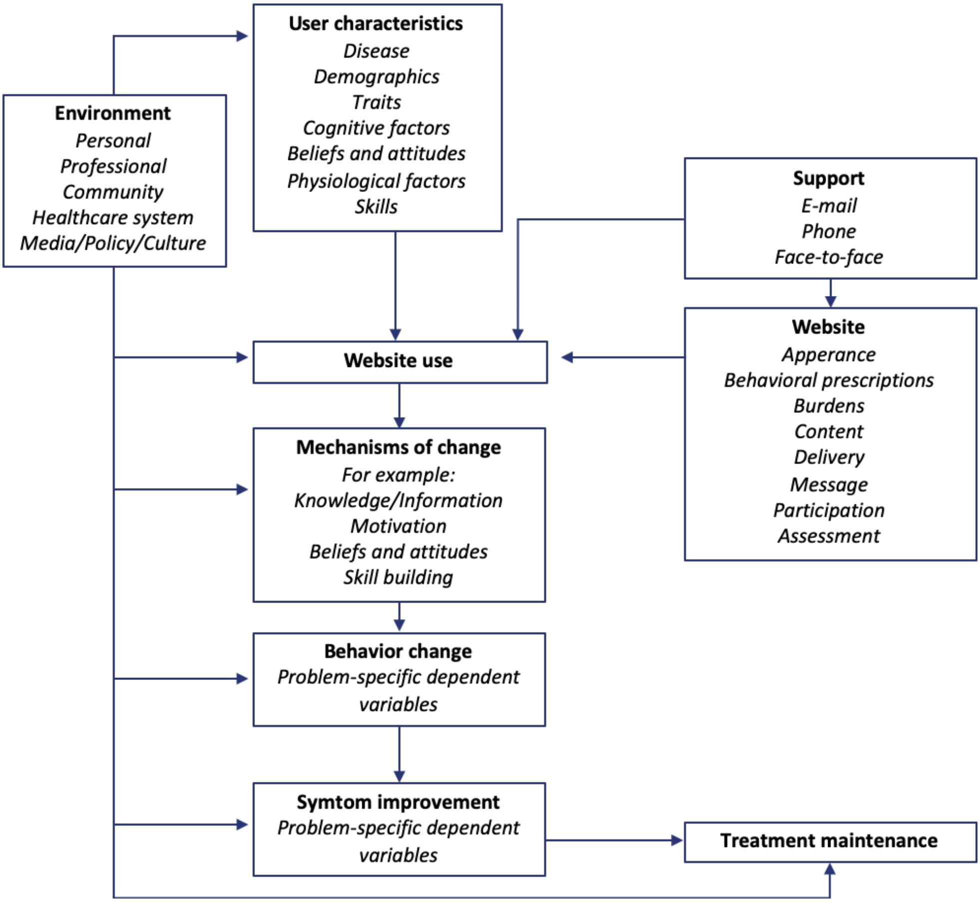

Figure 5 Model of behavior change for internet interventions (Ritterband et al., 2009).

In order to facilitate the evaluation of different interventions aimed a behaviour change, a taxonomy of behavioral change techniques (BCTs) has been developed (Abraham & Michie, 2008). The original taxonomy consisted of 26 clearly defined techniques, but was later revised and refined to include 40 techniques (Michie et al., 2011). The techniques are categorized into a set of theory-linked definitions of "behavior change." Categorization of the content of interventions has previously been lacking, making it difficult to distinguish particular techniques or content characteristics associated with effectiveness in different interventions. The possibility to more clearly describe the techniques used in an intervention may facilitate implementation and replication of effective intervention content, contributing to the clarification of the evidence base about behavior change. Web-based interventions that incorporate more BCTs tend to be more effective than interventions with fewer techniques (Webb et al., 2010). In T2D management, several BCTs have been associated with improvements in health behaviors, clinical outcome measures, and psychological outcomes (van Vugt et al., 2013).

Web-based interventions supporting diabetes management

Web-based interventions in diabetes care can be used to promote different aspects of diabetes self-management, e.g., problem solving, decision making, emotional management, or behavior change (Bendig et al., 2018). While some interventions focus solely on glucose monitoring, interventions targeting self-management generally adopt a more holistic outlook, informed by behavioral change theories. In order to be usable and engaging, the development of interventions should be grounded in the needs and perspectives of the intended users (Yardley et al., 2015; Pal et al., 2018). This approach can be applied at each stage of intervention development and evaluation, and involves the use of qualitative research, e.g., interview studies, to investigate attitudes, needs, and beliefs of the people who will use the intervention, identification of key issues the intervention needs to address, and the use of iterative modifications of the intervention based on users' feedback (e.g., how easy it is to use, how interesting the user thinks it is). Numerous interventions to support self-management of T2D have been developed and evaluated over the last years, presenting clinically significant improvements in both health outcomes and wellbeing (Kebede et al., 2018; Murray et al., 2017; Pal et al., 2018; Hadjiconstantinou et al., 2016). There are, however, challenges associated with web-based interventions, some of which will be reviewed in the following section.

Challenges

Although web-based interventions could be part of a solution to the strains on health expenditures world-wide due to the increasing prevalence of T2D, several important challenges need to be addressed (Pal et al., 2013). There is no clear picture of the "active ingredients" in diabetes self-management support. Long-term outcomes are scarce, and research on how to provide effective ongoing support is lacking (Shan et al., 2019). There also tends to be a problem with uptake of and access to educational programs, with less than 10% of individuals with diabetes attending such programs (Pal et al., 2018). Non-attendance can be attributed to financial, medical, and logistical reasons, but is also due to beliefs about education not being beneficial, or negative feelings towards education (Horigan et al., 2016). Although little experience of computer use, e.g., in older adults, may be perceived as a barrier to web-based diabetes management support, previous research has shown that even computer novices are willing to use this kind of support (Fell et al., 2000; Clark, 2008). However, dropout rates for web-based interventions tend to be high, and maintaining user engagement is often key for the success of interventions aimed at promoting lifestyle modification (Lie et al., 2017; Cotter et al., 2014).

Two main approaches have been suggested to improve uptake and maintain user engagement over time: the first is to maximize acceptability and usability of the intervention, so that individuals want to use it; and the second, to facilitate enough support so that individuals are able to use it (Pal et al., 2018). Michie et al. (2017) have proposed a number of key recommendations for developing and evaluating digital behavior change interventions. These include recommendations concerning methods for the development of digital interventions (e.g., using iterative development cycles to continuously update and adapt interventions), and for: understanding and promoting user engagement (e.g., by applying a mixed method approach to assess users' views and behaviors when engaging with the intervention); ensuring that the intervention is tailored to the users' needs and preferences; evaluating effectiveness; using data generated by the intervention to test and advance models and theories of behavior change; and generating evidence of cost-effectiveness.

Overall, there is a need for new ways to support lifestyle modifications in patients with T2D that could complement existing care and help support sustained improvements in glycemic control. The adjustment to having diabetes includes cognitive, emotional, and behavioral adjustment, but individuals with T2D are not always sufficiently supported to manage the transition in lifestyle that would result in improved glycemic control. More knowledge is needed regarding patient factors associated with diabetes management, in order to provide support to those who may need it the most. Web-based interventions have the potential of reach and accessibility and can be tailored to address the perceived problems of the patient group for whom the intervention is intended for. A person-based approach can inform both development and evaluation of such an intervention.

Aims

The overall aim of this thesis was to examine patient factors associated with glycemic control, to explore patients' perspectives on diabetes management and need for support, and to develop and evaluate a web-based intervention for individuals with T2D encouraging lifestyle change.

In **study I**, differences in glycemic control between different groups with respect to sex, level of education, civil status, age, and BMI, in individuals with T2D were examined. A further objective was to investigate whether any potential effect on glycemic variability was modified by sex.

The aim of **study II** was to examine if the psychological factors of perceived competence, appraisal of diabetes, and motivation were associated with glycemic control in individuals with T2D. The study further examined differences in these psychological factors in individuals with different diabetes duration.

Study III explored the needs of, and attitudes and barriers to diabetes self-management among, individuals with T2D, in order to inform the development of a new, web-based intervention. A further aim was to address participants' views on design and expectations on content of the intervention, and to explore patients' views on examples of self-affirmation in the context of diabetes management.

The primary aim of **study IV** was to examine the effect of a new, web-based lifestyle tool on glycemic control in individuals with T2D, and to investigate whether response to the tool was associated with frequency of exposure or pathophysiological characteristics of the participants.

Methods

Study designs

Studies I and II were observational cohort studies based on the larger project, "Detailed mapping of type 2 diabetes (DIACT)." The overall aim of DIACT was to map the main pathophysiological components of T2D progression, including lifestyle, social, and psychological factors, in addition to genetic and molecular factors. Participants in study I and II were measured at baseline and measurements were repeated every 6 months, with a total follow-up time of 24 months.

Study III was a qualitative interview study. Semi-structured interviews with individuals with T2D were used to collect data about experiences of diabetes management, followed by three additional study visits where participants gave feedback on features of the planned intervention.

Study IV was a randomized clinical trial with several secondary and exploratory outcomes, described in detail in Paper IV. Here, the primary outcomes are reported. The effect of the lifestyle tool was evaluated during a 12-week randomization period, followed by an open-label observation period of up to 3 years. Participants were randomized to wait for 12 weeks or access the tool immediately, after which the two groups were merged to assess long-term outcomes. Participants in the merged group were then compared to matched controls on usual care. The response to the tool was further examined in a subgroup of overweight and insulin-resistant participants, in order to investigate whether the effect of the tool was associated with these pathophysiological characteristics.

The studies presented in this thesis are summarized in Table 4.

Table 3 Overview of the studies.

	Study I	Study II	Study III	Study IV
Aim	Examine associations between sex, education, BMI, age, diabetes duration, and glycemic control over time	Examine associations between perceived competence, appraisal of diabetes, motivation orientation, and glycemic control over time	Explore patients' experiences of diabetes self-management, needs for further support, and views on a lifestyle intervention under development	Evaluate the effect of a lifestyle tool on glycemic control in individuals with T2D, and assess long-term outcomes of using the tool
Design	Cohort study with repeated measures and follow-up time of 24 months	Cohort study with repeated measures and follow-up time of 24 months	Qualitative interview study	RCT
Inclusion criteria	Age >35 years, T2D diagnosis	Age >35 years, T2D diagnosis	Age >35 years, T2D diagnosis	Age >35 years, T2D diagnosis, HbA1c ≥52 mmol/mol
Sample	158	158	22	370
Outcomes	HbA1c variability	Baseline HbA1c, HbA1c variability	–	HbA1c
Analysis method	Multivariable analysis of variance	Multiple linear regression analysis	Thematic analysis	*t*-test, linear regression analysis

BMI = body mass index; HbA1c = glycated hemoglobin; RCT = randomized controlled trial; T2D = type 2 diabetes.

Study setting

Participants in studies I and II were assessed at a diabetes daycare clinic at Scania University Hospital in Malmö, Sweden, by experienced diabetes nurses. Each visit included blood sampling and administration of questionnaires. Participants attended study visits during 2013 to 2017. The interviews for study III were conducted at Lund University's Clinical Research Centre (CRC) in Malmö, Sweden, during November 2014 to January 2015. Interviews were conducted at an office at CRC and lasted 1,5–2 hours. All interviews were conducted by a licenced psychologist with knowledge about T2D and diabetes research, who had no prior relationship to the participants. Following the interviews, participants attended three additional study visits where content from the web-based intervention under development was demonstrated on a computer and tested by the participants. These visits were held in the same office at CRC as the interviews, and by the same psychologist. Participants in study IV were assessed at a study centre located at Scania University Hospital, Malmö, Sweden, by experienced diabetes nurses. The study visits lasted approximately 20 minutes. Study personnel were not involved in the randomization procedure or in the participants' activities on the lifestyle tool, and were instructed to remain neutral at visits. Technical problems were referred to a study coordinator.

Participants

Participants in all studies were recruited from the All New Diabetics in Scania (ANDIS) cohort, or via advertisement (study IV). The aim of the research and quality assurance project ANDIS is to register all new diabetes cases in Scania County in Sweden (approximately 1,200,000 inhabitants) (Lund University, 2021). Participants in studies I–III were enrolled in the DIACT study. Study participants were recruited based on their T2D diagnosis and age (>35 years). Altogether 2,000 individuals were invited to take part in the DIACT study, 195 of whom were included for participation after screening. The final sample for studies I and II was 158 individuals, after exclusion of participants for medical reasons (*n*=3), death prior to follow-up (*n*=2), fewer than five HbA1c measurements during the study time (*n*=19), and dropout before follow-up (*n*=13). The characteristics of the participants in studies I and II are presented in Tables 5 and 6.

Table 5 Characteristics of participants in study I (*N*=158).

Age (years)	
Mean (SD)	67.6 (7.0)
<65 years	25.9 (41)
65–70 years	35.4 (56)
>70 years	38.6 (61)
Sex	
Women	34.8 (55)
Men	65.2 (103)
BMI (*n*=157)	
Normal weight (BMI≤24.99)	12.7 (20)
Overweight (BMI=25–29.99)	48.4 (76)
Obese (BMI≥30)	38.9 (61)
Education level (*n*=142)	
Elementary school	30.3 (43)
High school	40.1 (57)
University	29.6 (42)
Civil status (*n*=147)	
In a relationship	81.6 (120)
Single	18.4 (27)
Time since diagnosis (years), mean (SD)	4.1 (3.4)
Baseline HbA1c, mean (SD)	
mmol/mol	46.9 (7.5)
%	6.4 (0.7)
Prescribed metformin	72.2 (114)
Prescribed insulin (*n*=156)	7.1 (11)

Data is presented as percentage (*n*) unless otherwise indicated. BMI = body mass index; HbA1c = glycated hemoglobin; SD = standard deviation.

Table 6 Characteristics of participants in study II.

Sex, % (*n*)	
Women	34.2 (54)
Men	65.8 (104)
Age, years	
Mean (SD)	67.5 (7.0)
Range	44–78
Years since diagnosis	
Median (IQR)	3.5 (1.0–6.0)
Range	0–20
Baseline HbA1c, mmol/mol	
Mean (SD)	46.9 (7.5)
Prescribed metformin, % (*n*)	71.5 (113)
Prescribed insulin, % (*n*) (*n*=156)	7.1 (11)
Other antidiabetic drugs (sulfunylureas, glitazones, DPP IV inhibitors, GLP-1 agonists), % (*n*)	10.8 (17)
Negative appraisal of diabetes, mean (SD) (*n*=135)	15.0 (3.1)[a]
Perceived competence, mean (SD) (*n*=143)	5.4 (1.3)[b]
Motivation orientation, mean (SD)	
Autonomous (*n*=141)	5.8 (1.2)[b]
Controlled (*n*=140)	3.7 (1.5)[b]

[a]Total score range 7–35; [b]total score range 1–7; HbA1C = glycated hemoglobin; IQR = interquartile range; SD = standard deviation.

For study III, participants were purposefully sampled based on age, disease duration, treatment, and HbA1c, to ensure a diverse sample. A total of 30 individuals (of the 195 included in the DIACT study) were contacted for participation, 22 of whom were interested in participating, twelve (54.5%) men and ten (45.5%) women. Participants who had been diagnosed with T2D ≤3 years previously constituted 72.7% (*n*=16), and 63.6% (*n*=14) had been prescribed metformin. Mean age was 68.7 years (SD 8.1, range 44–78).

For study IV, 667 individuals underwent screening and 370 were enrolled. Study participants eligible for participation were older than 35 years, had a T2D diagnosis, and HbA1c ≥52 mmol/mol. The participants were randomized to access the tool immediately (*n*=184; 41 lost to follow-up) or wait for 12 weeks (*n*=186; 16 lost to follow-up). Matched controls in study IV were selected from the ANDIS cohort. The controls were matched for sex, age, BMI, and HbA1c. Characteristics of the participants in study IV are described in Table 7.

Table 7 Characteristics of participants in study IV.

	Tool (*n*=184)	Usual care (control) (*n*=186)	All (*n*=370)
Male sex, *n* (%)	117 (63.6)	112 (60.2)	229 (61.9)
Age (years), mean (SD)	63.6 (9.6)	63.0 (9.8)	63.3 (9.7)
Diabetes duration (years), mean (SD)	4.2 (1.4)	4.1 (1.4)	4.2 (1.4)
BMI, mean (SD)	31.0 (5.3)	31.2 (5.1)	31.1 (5.2)
HbA1c, mmol/mol, mean (SD)	63.6 (10.7)	62.9 (9.7)	63.2 (10.2)
Glucose-lowering medication, *n* (%)			
None	7.0 (4.0)	7 (3.9)	14 (3.9)
Oral only	117(66.5)	121 (66.1)	238 (66.1)
Oral and insulin	39 (22.2)	40 (21.9)	79 (21.9)
Insulin only	13 (7.4)	15 (8.2)	29 (8.1)
Socioeconomic status, *n* (%)			
Employed	67 (43.2)	78 (45.9)	146 (44.8)
Unemployed	5 (3.2)	2 (1.2)	7 (2.1)
Retired	77 (49.7)	79 (46.5)	156 (47.9)
Sick leave >3 months	6 (3.9)	8 (4.7)	14 (4.3)
Taking care of own household	0 (0)	3 (1.8)	3 (0.9)
Highest education, *n* (%)			
Basic level	26 (17.6)	25 (15.2)	51 (16.2)
Medium level	47 (31.8)	52 (31.5)	99 (31.5)
University ≤3 years	28 (18.9)	26 (15.8)	54 (17.2)
University >3 years	47 (31.8)	62 (37.6)	110 (35.0)

BMI = body mass index; HbA1c; glycated hemoglobin; SD; standard deviation.

Development of lifestyle tool

The development of the lifestyle tool evaluated in study IV was preceded by considerations concerning the purpose of the intervention, its theoretical framework, the characteristics of the target group, and identified problems, needs, and challenges that the intervention may need to address, informed by the results from study III. Both patients and health care professionals tested early versions of the tool and gave feedback on design, usability, and perceived relevance, as well as suggestions for improvements.

The tool is built around 80 different themes focusing on topics relevant for diabetes self-management, such as diet and exercise, but also on other topics, such as stress management and decision making. A set of themes focusing on existential health that the WHO has proposed was also included (WHOQOL SRBP Group, 2006). Each theme incorporates several BCTs, which previously have been defined in order to better understand the effective elements of lifestyle interventions (Pal et al., 2013; Van Vugt et al., 2013; Michie et al., 2011). The themes consist of a self-assessment test aimed at raising awareness of current behavior, an exercise (e.g., time prioritization, mindful eating, methods to cope with automatic thoughts), and information about health and lifestyle. At the end of every theme, the user gets to choose a question or write their own question, related to the theme (e.g., "How can I prioritize my health?," "What is the smallest thing I can do to get more physical activity into my everyday life?," or "When am I the most vulnerable to short-term thinking?"). When the user has completed a theme and chosen a personal question, he or she is encouraged to consider the question in his or her daily life, and return to the tool within 2 weeks. When returning to it, there is an opportunity to briefly comment on whether the question has led to any behavioral changes. The tool is designed to be used as a continuous support, rather than as a fixed treatment program. It includes a function for bookmarking texts and writing comments, and a personal overview of themes completed, questions asked, and reported changes made in daily life.

Assessments and outcomes

Study I

Sociodemographic factors, such as participants' level of education, civil status, time since diagnosis, and use of metformin, were assessed with a questionnaire at study start, and height and weight were measured. Education was categorized into three response categories, "elementary school", "high school", and "university", and civil status was grouped into two groups, "in a relationship" and "single." Standard BMI groups were used, i.e. normal weight (BMI=18.50–24.99), overweight (BMI=25.00–29.99), and obesity (BMI>30). Age was based on date of birth and categorized into three groups: <65 years, 65–70 years, and >70 years. Time since diagnosis was measured in years, and treatment with metformin was categorized as "yes" or "no." Glycemic control was measured as HbA1c and HbA1c variability. Level of HbA1c was assessed at five measurement points: at baseline, and at 6, 12, 18, and 24 months. Variability in HbA1c was calculated as the SD of the measurements, as well as a normalized measure of variability, the coefficient of variation (CV), which was calculated as (SD/mean HbA1c) * 100. Exposure variables in study I were education, civil status, BMI, age, and diabetes duration. Outcome was HbA1c and HbA1c variability.

Study II

Perceived competence, appraisal of diabetes, and motivation orientation were assessed with questionnaires repeatedly, at every study visit. Baseline measures of these psychological variables were analysed in study II. Perceived competence was measured with the Perceived Competence for Diabetes Scale (PCDS) (Williams et al., 1998), including four items averaged to form a total score. Higher scores indicated a greater level of perceived competence in own ability to manage diabetes. Appraisal was measured with the Appraisal of Diabetes Scale (ADS) (Carey et al., 1991), including seven items summarized to form a total score. Higher scores indicated a more stressful impact of diabetes. Motivation orientation was measured with the Treatment Self-Regulation Questionnaire (TSRQ) (Levesque et al., 2006), including eight items distributed on two subscales and averaged to form a total score on each subscale. Higher scores on either subscale represent a greater level of internal and external motivation, respectively. Glycemic control was measured as HbA1c and HbA1c variability, assessed in the same way as in study I. Exposure variables in study II were perceived competence, appraisal of diabetes, and motivation orientation. Outcomes were HbA1c and HbA1c variability.

Study III

The semi-structured interview in study III covered the following topics: the experience of having diabetes, barriers to making lifestyle changes, perceived competence of diabetes self-management, previous experience of making lifestyle changes, diabetes self-management support, and goals. Following the interviews, participants made three additional study visits. At these study visits, participants were presented with computer-based assignments encouraging self-reflection, including identifying personal values, prioritizing among goals, and written examples of diabetes self-management. The assignments were influenced by self-affirmation theory. The participants gave verbal feedback on the assignments, focusing on both content and usability, but also on the use of self-affirmation in the context of diabetes self-management. Examples of feedback questions that were used with the participants can be found in table 8. The assignments were iteratively modified based on the participants' feedback. All interviews were recorded and transcribed. Feedback on the assignments was summarized in writing and checked against audio recordings for accuracy.

Table 8 Examples of feedback questions study visit 2-4.

What do you think of the treatment concept in general?
What opportunities or barriers do you see in the treatment concept being web-based?
What needs do you see as central to diabetes management and what is needed (by a web-based treatment concept) to meet them?

Study IV

Participants in study IV made study visits every 3 months during the first year, and thereafter every 6 months over a total period of up to 3 years. The study visits included blood sampling to assess HbA1c and measurements of length and body weight. Participants were also asked to report any changes in medication. Age, sex, BMI, time since diabetes diagnosis, and current glucose-lowering treatment were assessed at the first study visit. After the first visit, participants received an email with a web link to a personal study account and instructions on how to get started using the tool. Via the link, participants were randomized to either have immediate access to the tool or to wait for twelve weeks. Participants on wait were invited to a second study visit after twelve weeks. The visit included blood sampling. After the visit, they received a web link to access the tool.

The primary outcomes in study IV were change in HbA1c from baseline to 12 weeks between randomization groups, and change in HbA1c from baseline to 1 year in participants using the tool as recommended (biweekly or more frequently), compared to matched controls. The effect of the intervention at different usage patterns was also studied to end of follow-up (average 730 days). The effect of the tool in the mild obesity-related diabetes (MOD) subgroup was examined by assessing change in HbA1c after 12 weeks in participants with MOD characteristics, compared to MOD participants on wait. Cost-effectiveness of the tool was examined by comparing health economic consequences of using the tool, to current standard of care.

Analyses

Analyses in studies I, II and IV were performed using IBM SPSS Statistics for Macintosh, version 23.0–26.0 (IBM Corporation, Armonk, NY, US). The alpha level was set to 0.05 in all analyses. The coding and analysis process in study III was conducted using the qualitative data analysis software program ATLAS.ti, version 8.2.4 (ATLAS.ti Scientific Software Development GmbH, Berlin, Germany).

Study I

Descriptive statistics (percentage or means, and SD) were computed for sex, level of education, civil status, age, BMI, medication (metformin, insulin), time since diagnosis, age, and HbA1c at baseline. Group differences in HbA1c variability and baseline HbA1c were examined using multivariable analysis of variance, with all sociodemographic variables included as independent variables. Potential effect modifications were explored by including interaction effects between sex and BMI, and between sex and civil status, when evaluating differences in HbA1c variability. Diabetes duration and metformin treatment were included as potential confounding factors when analysing differences in HbA1c. Baseline HbA1c was added to these as potential confounder when analysing differences in HbA1c variability. Results are presented as mean differences with 95% confidence intervals (CIs).

Study II

Descriptive statistics (percentage or means, and SD) were computed for sex, age, time since diagnosis, HbA1c at baseline, medication (metformin, insulin, other antidiabetic drugs), appraisal of diabetes, perceived competence, and motivation (autonomous, controlled). Multiple linear regression analyses were conducted to determine if psychological factors predicted HbA1c variability over time. Psychological factors were entered as independent variables in the model, and HbA1c variability was included as dependent variable. The analyses were stepwise adjusted for the potential confounding factors sex, age, diabetes duration, metformin treatment, and baseline HbA1c. Separate crude models for each psychological factor were first built, and in the final analysis all psychological factors were included in the same, adjusted model. Multiple linear regression was also used to examine cross-sectional associations between psychological factors and baseline HbA1c. Sex, age, diabetes duration, and metformin treatment were included as potential confounders. Univariate analysis of variance (ANOVA) was further used to examine differences regarding psychological factors between groups with different diabetes duration. Results from the linear models are reported as standardized beta coefficients with 95% CIs.

Study III

Thematic analysis was used to analyze all data. Data collection and analysis were attempted to be transparent and systematic, and interpretations were derived directly from the data (Denzin & Lincoln, 1994). The interview guide was used as an overarching framework of themes, and functioned as a starting point for generating initial codes. When all data was coded, the different codes were sorted into potential subthemes, which then were reviewed and developed into main themes based on what aspects of interest the themes were considered to capture. The process of analysis followed Braun & Clarke's (2013) five phases: familiarization, generating initial codes, generating themes, reviewing themes, and defining themes.

Study IV

Sample size of randomization groups was calculated to ensure at least 80% power at alpha = 0.05 to detect a significant difference between the groups, assuming that the true treatment effect of the tool is 2 mmol/mol over 12 weeks with an SD of 6 mmol/mol, and 5 mmol/mol over 1 year with an SD of 7 mmol/mol, for changes in HbA1c. Outcomes were compared between intervention and control groups (waitlisted controls and matched controls) using independent *t*-tests. Corresponding analyses were performed for participants who used the tool less frequent, i.e., monthly and bimonthly.

To examine the effect of the tool in MOD patients, study participants and matched controls were categorized as MOD and non-MOD, based on clustering methodology as described by Ahlqvist et al. (2018). Potential effect modifications were explored using a linear model, including interaction effects between randomization groups and MOD/non-MOD characteristics, when evaluating differences in HbA1c after 12 weeks. Comparisons between the groups were adjusted for baseline HbA1c. Results are presented as mean differences with 95% CIs.

The health economic consequences of the tool compared to standard care were modeled using the Swedish Institute for Health Economics (IHE) diabetes cohort, which uses cohort data to estimate the cost-effectiveness of treatment for diabetes (Lundqvist et al., 2014). The analysis was based on assessment of risk factor control and on a number of assumptions regarding baseline characteristics to model the simulation. These results are presented as total estimated cost savings and quality-adjusted life-years (QALYs), which is a summary measure of health outcome that combines an individual's health-related quality of life with survival (Whitehead & Ali, 2010).

Ethical considerations

Individuals with T2D are a large and growing group, and there is a need to better understand the different pathophysiological as well as psychological aspects of the disease in order to improve treatment options and support adequate self-management of diabetes. The T2D population is also a vulnerable patient group, often of older age and with a chronic condition that may be considered stigmatizing. Due to these and other concerns, several ethical considerations have been taken into account during the work on this thesis.

As a framework in medical ethics, four clusters of moral principles can be considered: respect for autonomy, non-maleficence, beneficence, and justice (Beauchamp & Childress, 2013). *Respecting autonomy* can include disclosing accurate and detailed information about the study procedure, as well as obtaining informed consent from study participants. *Non-maleficence* encompasses the principle of avoiding the causation of harm, by making judgements to minimize level of harm or burden for the patient. *Beneficence* includes balancing benefits against risks and costs, while the principle of *justice* is concerned with fair distribution of benefits, risks, and costs.

To ensure that the participants' participation in the research was voluntary, informed consent was obtained for all studies, with information about what to expect from participation and about the right to discontinue study participation at any time. Information was given both in writing and verbally. The overall risks of the studies were judged to be small. Blood samples were collected according to routine procedures and by experienced diabetes nurses. The observational study design of study I and II did not expose the participants to any obvious risks, and study participants continued their regular care during their participation in the studies, minimizing the risk of undetected deterioration of health.

Questions about lifestyle habits in relation to diabetes self-management can trigger feelings of guilt and shame. The interviews in study III were therefore carefully prepared by developing a semi-structured interview guide, which was reviewed by both a licenced psychologist and a physician before the interviews were conducted. All interviews were conducted by a psychologist with knowledge about diabetes. In study IV, the wait-list design granted all participants access to the intervention, weighing the benefits of participating against the potential harm of not receiving the intervention as would otherwise have been the case. All data collected via the lifestyle tool was stored on a secure server, and exported data was tied only to study identity, to ensure anonymity. Personalized passwords were used to access the tool, and participants used the tool at home and at their own pace, with no interference from the study team, to warrant the integrity of participant data.

The studies were reviewed and approved by the Regional Ethics Review Board in Lund, Sweden (Dnr 2013/84, EPN Lund 2014/702; EPN Lund 2015/563), and performed in accordance with the Declaration of Helsinki and Good Clinical Practice.

Results

Studies I and II: Sociodemographic and psychological factors associated with glycemic control

Results from study I showed a significant but small difference in HbA1c variability (SD) between men and women, where men had greater glycemic variability than women (mean difference 1.44 mmol/mol (95% CI 0.58–2.31), p=.001). There was also a statistically significant difference between BMI groups, where individuals with a BMI indicative of obesity showed greater glycemic variability than those with normal weight (mean difference 1.56 mmol/mol (95% CI 0.25–2.88), p=.020) (Table 9). No statistically significant differences in HbA1c at baseline between groups based on sex, education, civil status, age, or BMI, were found. There were further no significant interactions effects between sex and BMI, or between sex and civil status.

Table 9 Multivariable analysis of variance of glycated hemoglobin (HbA1c) variability (mmol/mol, %) in different sociodemographic groups.

	HbA1c variability, mmol/mol			HbA1c variability, %		
	Mean (95% CI)	*Mean difference between groups (95% CI)*	*p*	*Mean (95% CI)*	*Mean difference between groups (95% CI)*	*p*
Civil status						
In a relationship (*n*=116)	2.94 (2.40, 3.49)			0.26 (0.21, 0.32)		
Single (*n*=26)	3.72 (2.76, 4.69)	-0.78 (-1.82, 0.26)	.142	0.34 (0.25, 0.43)	-0.08 (-0.18, 0.02)	.126
Sex						
Men (*n*=96)	4.06 (3.41, 4.70)			0.37 (0.31, 0.43)		
Women (*n*=46)	2.61 (1.81, 3.42)	1.44 (0.58, 2.31)	.001	0.24 (0.16, 0.31)	0.13 (0.05, 0.21)	.002
BMI						
Normal weight (*n*=19)	2.54 (1.36, 3.71)			0.24 (0.13, 0.35)		
Overweight (*n*=69)	3.37 (2.69, 4.06)	0.84* (-0.43, 2.10)	.192	0.31 (0.24, 0.37)	0.07* (-0.05, 0.19)	.244
Obese (*n*=54)	4.10 (3.37, 4.83)	1.56* (0.25, 2.88)	.020	0.36 (0.29, 0.43)	0.13* (0.00, 0.25)	.005
Education						
Elementary school (*n*=43)	3.40 (2.51, 4.28)			0.32 (0.23, 0.40)		
High school (*n*=57)	3.44 (2.66, 4.21)	0.04† (-0.95, 1.03)	.938	0.31 (0.23, 0.38)	0.01† (-0.10, 0.08)	.827
University (*n*=42)	3.17 (2.36, 3.98)	-0.23† (-1.28, 0.83)	.673	0.28 (0.21, 0.36)	-0.03† (-0.13, 0.07)	.527
Age						
<65 years (*n*=38)	3.65 (2.76, 4.54)			0.34 (0.25, 0.42)		
65–70 years (*n*=51)	3.51 (2.71, 4.31)	-0.14‡ (-1.19, 0.91)	.789	0.30 (0.22, 0.38)	-0.04‡ (-0.14, 0.06)	.469
>70 years (*n*=53)	2.84 (2.05, 3.64)	-0.81‡ (-1.86, 0.25)	.132	0.27 (0.20, 0.35)	-0.06‡ (-0.16, 0.04)	.209

*mean difference in relation to BMI indicating *normal weight*; †mean difference in comparison to education group *elementary school*;

‡mean difference in comparison to age group *<65 years*. BMI = body mass index; SD = standard deviation.

In study II, negative appraisal of diabetes was significantly associated with both higher HbA1c variability (CV) (β=0.21, 95% CI 0.04 to 0.57, p=.025) and higher baseline HbA1c (β=0.26, 95% CI 0.17 to 1.10, p=.008), in the adjusted models. Greater autonomous motivation was associated with higher baseline HbA1c (β=0.27, 95% CI 0.44 to 2.75, p=.007), and controlled motivation was associated with lower baseline HbA1c (β=-0.19, 95% CI -1.77 to -0.06, p=.036) (Tables 10–11). No significant differences regarding psychological factors were found between groups with different diabetes duration.

Table 10 Multiple linear regression analysis between psychological factors and glycated hemoglobin (HbA1c) variability (SD, CV) during a 24-month follow-up.

	Crude models				Adjusted model			
	B	95% CI	β	*p*	B	95% CI	β	*p*
Negative appraisal of diabetes								
SD	0.20	0.07, 0.33	0.22	.003	0.15	-0.01, 0.31	0.17	.052
CV	0.34	0.11, 0.57	0.24	.004	0.31	0.04, 0.57	0.21	.025
Perceived competence								
SD	-0.42	-0.73, -0.12	-0.20	.006	-0.31	-0.71, 0.09	-0.14	.131
CV	-0.79	-1.31, -0.26	-0.23	.004	-0.53	-1.22, 0.16	-0.15	.133
Autonomous motivation								
SD	-0.16	-0.47, 0.16	-0.07	.325	0.11	-0.27, 0.50	0.05	.567
CV	-0.34	-0.88, 0.20	-0.10	.219	0.17	-0.49, 0.83	0.05	.613
Controlled motivation								
SD	-0.05	-0.31, 0.21	-0.03	.718	-0.13	-0.41, 0.15	-0.07	.351
CV	-0.15	-0.60, 0.30	-0.05	.520	-0.30	-0.79, 0.18	-0.10	.220

CI = confidence interval; CV = coefficient of variation; SD = standard deviation.

Table 11 Multiple linear regression analysis between psychological factors and baseline level of glycated hemoglobin (HbA1c) (mmol/mol) in the independent and mutually adjusted model.

	Crude models				Adjusted model			
	B	95% CI	β	*p*	B	95% CI	β	*p*
Negative appraisal of diabetes	0.70	0.30, 1.11	0.29	.001	0.64	0.17, 1.10	0.26	.008
Perceived competence	-1.10	-2.06, -0.14	-0.19	.025	-1.07	-2.29, 0.15	-0.18	.086
Autonomous motivation	0.46	-0.53, 1.45	0.08	.360	1.59	0.44, 2.75	0.27	.007
Controlled motivation	-0.60	-1.41, 0.22	-0.12	.151	-0.91	-1.77, -0.06	-0.19	.036

CI = confidence interval.

Study III: Participants' experiences of diabetes self-management and perspectives on the development of an online lifestyle support

Participants in study III reported a varying sense of urgency and distress related to diabetes management, and described difficulties identifying themselves with the lifestyle changes to improve health that they were recommended to do. The participants further described different barriers to successful diabetes management, such as lack of motivation, physical barriers (e.g., pain, older age), and emotional barriers (e.g., stress, feelings overlooked by health care professionals). Overcoming current habits, such as sedentariness or irregular meals, were also reported as a struggle by some of the participants. Participants expressed a need for more information about diabetes and related health risks, as well as a need for support from both professionals and significant others. Both autonomy support and emotional support were described as important.

Themes generated regarding participants' views on the utility of a web-based lifestyle tool, suggestions for design, and expectations on content are presented in Tables 12–14.

Table 12 Participants' descriptions of how they would use a web-based tool to support lifestyle changes.

Encouragement	Information	Prioritization
Contact with others in the same situation	Getting answers to diabetes-related questions	Getting help with setting goals
Contact with health care professionals	Access to reliable information about T2D and diabetes self-management	Gaining understanding of the seriousness of T2D in order to make healthy choices
Sharing experiences of diabetes with others	Tracking of own blood glucose levels and blood pressure	Being reminded about important values
Receiving encouragement from others		Getting help to understand what one needs to change when it comes to lifestyle habits
		Support in becoming aware of associations between own habits and blood glucose values

Receiving encouragement and information were described as useful aspects of a web-based tool, since these features were perceived to increase motivation, help alleviate distress, and provide practical help in making beneficial lifestyle changes. Getting help to prioritize was described in terms of setting goals and getting support in becoming aware of how one's habits affect glycemic control (Table 12).

Table 13 Participants' suggestions for design of a web-based tool to support lifestyle changes.

Accessible	Reliable
Easy to navigate (not too many complicated features), easy to get an overview, adaptable for those with poor eyesight, easy to know what is what, short explanations/tutorials for the different features	Up-to-date information
Possible to use on the cellphone or tablet, not only the computer	Information about who is behind the tool
Personalized	Regular updates
Possible for users to give feedback if things are not working	A layout that gives a "serious" impression

Participants made several suggestions for design elements to make the tool *accessible* to them, including introducing different features in short tutorials, and facilitating easy access to an overview of the tool. They suggested that the tool's *reliability* was dependent on trustworthy information and regular updates; and further suggested that a tool whose layout gave a serious impression, thus matching the target group, would be considered reliable (Table 13).

Regarding content, emphasis was on different ways to personalize content, track progress, and help focusing on personal goals and motivations (Table 14).

Table 14 Participants' expectations on content of a web-based tool to support lifestyle changes.

Track changes	Set goals	Personalize content
Graphical presentations	Tool for planning, e.g., diary	Tailored information
Tool for registering blood glucose levels, weight, and body measures, dietary intake, and physical activity	Possibility to evaluate goals and goal attainment	Practical tips and advice
Possibility to track the relationship between, e.g., diet and blood glucose levels	Focus on possibilities, rather than having someone tell you what to do	Help with individual needs related to diabetes management, e.g., stress management
		Possibility to get in touch with health care professionals

Participants reported the use of self-affirmation as a help to step out of his or her comfort zone and to be self-critical. Some expressed that the approach was too personal or difficult to understand, others described that it helped them to focus on their own responsibility and to normalize having diabetes. Participants further described it as helpful to be supported to put their own words on things that they would like to be different. Being reminded about important values and life choices was described as motivating.

Study IV: Evaluation of an online lifestyle tool to support diabetes management

Twenty-five of the participants randomized to access the tool immediately, and eight randomized to wait, discontinued before the second visit. To enable standardized comparisons between the groups, the accepted interval of days between visits was 60–120 days. Sixteen participants assigned to the tool and eight on usual care did not attend a second visit within this time frame and were not included in the comparison of randomization groups. The randomization groups were merged after the second visit, enabling all participants access to the tool for the long-term follow-up (Figure 6).

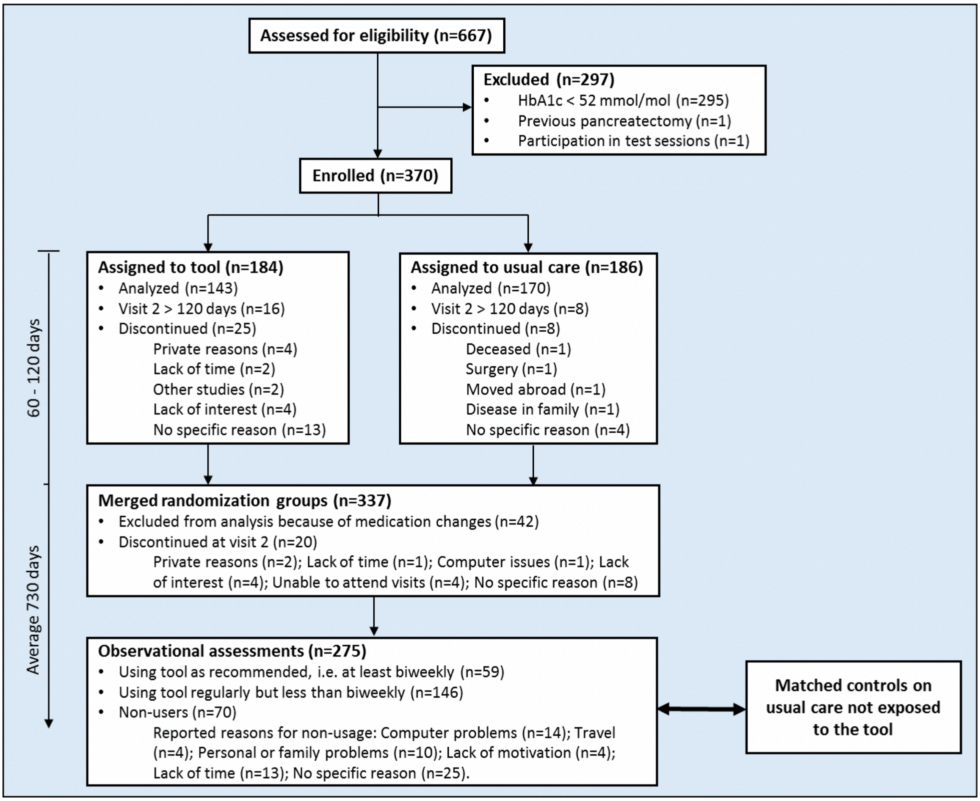

Figure 6 Participant flow as CONSORT diagram.

Results for the randomization period showed that participants who used the tool had a significant decrease in HbA1c compared to those randomized to wait (mean difference -2.0 mmol/mol (95% CI -3.8 to -0.2, p=.030)). Furthermore, there was a pronounced effect of the tool in participants with MOD characteristics, compared to

MOD participants on wait (mean difference -8.4 mmol/mol (95% CI -13.5 to -3.3)). Additionally, a significant interaction effect between randomization group and MOD/non-MOD characteristics was identified.

In the long-term follow-up, there was a correlation between exposure to the tool and the magnitude of metabolic improvement from baseline to 1 year. Participants using the tool at least biweekly during the first year significantly lowered their HbA1c levels compared to matched controls (mean difference -7.3 mmol/mol (95% CI -12.2 to -2.4, p=.004)) (Figure 7).

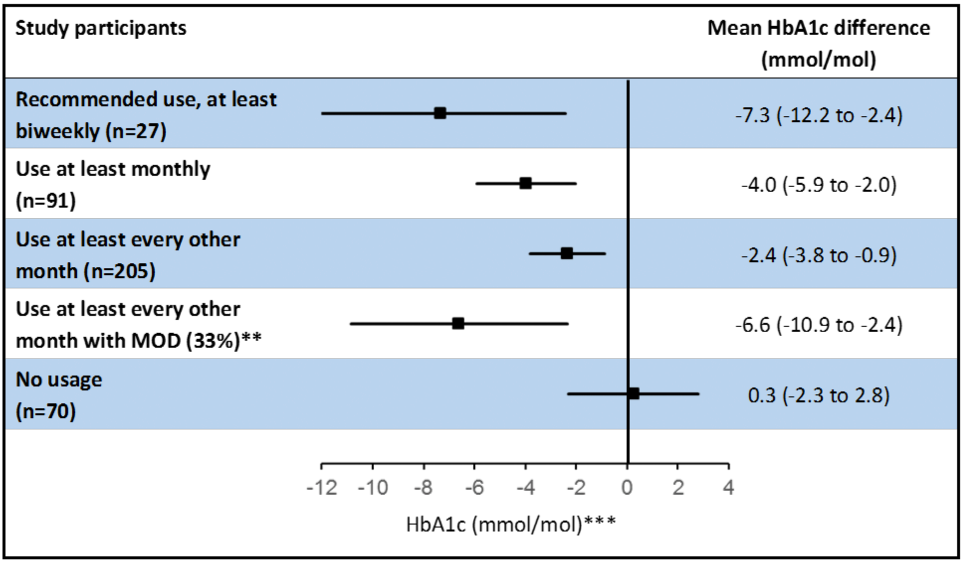

Figure 7 Change in glycated hemoglobin (HbA1c) from baseline to one year in study participants at different usage patterns compared to controls.

*Estimated differences between study participants and matched controls are presented as means (95% confidence intervals (CIs)).

**Changes in HbA1c levels when the tool was used at least every other month in participants with mild obesity-related diabetes (MOD) compared to matched controls with MOD. A total of 32%, 28%, 33%, and 21% of participants using the tool at least biweekly, monthly, and bimonthly, and non-users, respectively, had MOD.

***Plots of mean HbA1c difference between participants and controls with 95% CIs.

Over the entire follow-up period of up to 1,021 days (average 730 days, IQR 430–1,021 days), participants using the tool biweekly had a significant reduction in HbA1c compared to matched controls (mean difference -6.5 mmol/mol (95% CI -9.0 to -4.0, p<.0001)). Those using the tool less frequently also had a significant reduction in HbA1c compared to matched controls (Table 15).

Table 15 Changes in glycated haemoglobin (HbA1c) from baseline to end of follow-up (average 730 days) in participants using the tool compared with controls on usual care.

Endpoint	Mean difference (95% CI)		
	At least weekly usage (*N*=59)	**At least monthly (*N*=144)**	**At least bimonthly (*N*=205)**
Glycated haemoglobin level – mmol/mol	-6.5 (-9.0 to -4.0)	-4.2 (-5.9 to -2.4)	-3.6 (-5.2 to -2.1)

When analyzing the health economic consequences of the tool, participants using the tool as recommended had a reduced risk for diabetic complications due to improved risk factor control. For every patient using the tool biweekly, implementation of the tool was estimated to result in cost savings of 4,116 US$ and 0.5 more QALYs, over a 20-year simulation period.

Discussion

The results of the studies included in this thesis suggest that certain patient factors, namely, male gender, obesity, and a negative emotional experience of having diabetes, are associated with greater HbA1c variability, an emerging measure of glycemic control indicating the presence of hyper- or hypoglycemia. Results further suggest that there is a need for more personalized support promoting patient autonomy, in response to patients' perceived disconnect between recommended lifestyle advice and life context, and difficulties in implementing long-term changes. Finally, improved glycemic control was demonstrated in patients using a web-based intervention that encourages self-reflection and supports patients to make decisions based on health information related to diabetes self-management. The results add to the understanding of factors contributing to glycemic control, and of patient-perceived problems in relation to diabetes self-management, and present a new, web-based intervention to support long-term diabetes self-management.

Patient factors associated with glycemic control

Results of studies I and II indicate that certain patient characteristics are associated with decreased glycemic control in T2D, providing further insight into the heterogeneity of the T2D patient population. Greater HbA1c variability was observed in men and individuals with obesity. These groups had a HbA1c variability above a suggested threshold of 3.3 mmol/mol for clinical relevance, indicating that they may be more vulnerable to future diabetes complications, since the frequency and magnitude of glucose variations has been proposed as an additional risk factor for future complications related to diabetes (Hirakawa et al., 2014; Nalysnyk et al., 2010; Kilpatrick et al., 2012). The results are in line with previous research, suggesting that those individuals with T2D who are most likely to have high glycemic fluctuations are men and those with a high BMI (Noyes et al., 2017).

Although rarely considered in clinical contexts, biological and psychosocial differences between men and women influence T2D development and progression (Gonzalez-Zacarias et al., 2016). In general, women with T2D tend to have a less favourable outlook than men. Differences in, e.g., sex hormones and body fat distribution are associated with insulin sensitivity, and women show a stronger obesity–diabetes risk association. Women also appear to be more sensitive to modifiable social factors for future diabetes development (Kautzky-Willer et al., 2016). Variability in HbA1c is likely influenced by several factors, including lifestyle factors, which could explain why men and women differ with regard to glycemic stability. Another issue that was raised in these studies concerns treatment of near-normal HbA1c levels in the identified groups, since overtreatment could amplify HbA1c variability. As a precautionary measure, Prentice et al. (2016) suggest adherence to clinical guidelines recommending individualized HbA1c treatment targets, rather than a strive towards near-normal glucose control in all patients. This may be of particular importance in the identified groups.

In study II, a more negative emotional appraisal of diabetes was associated with both increased HbA1c and greater variability in HbA1c, highlighting that the emotional impact of diabetes may influence glycemic control. Results from study II regarding the association between psychological factors and glycemic control were somewhat inconclusive, since effect sizes were small and the role of self-management behaviors could not be ruled out. Although no significant association between perceived competence and HbA1c was found in study II, the importance of perceived competence for diabetes management has in previous studies been emphasized, and increased patient competence is largely believed to be a pathway to improved self-management of diabetes (Trouilloud & Regnier, 2013; Williams et al., 2005). It is likely that perceived competence may motivate health behaviors that result in improved biological markers of health; moreover, diabetes self-management behaviors have been found to mediate the relation between change in perceived competence and change in glycemic control (Williams et al., 2004). It is also likely that self-care behaviors would mediate the relationship between appraisal of diabetes and glycemic control, since perceptions of a condition as very serious, coupled with low belief in self-agency to affect the course of the condition, are associated with reduced self-care behaviors (Skinner et al., 2019).

The association between psychological factors and HbA1c was further examined prior to the construction of the lifestyle tool (see Paper IV Supplementary appendix, Table 2). The analysis was made over a longer period of time and in a slightly larger sample than in study II. Results showed that higher perceived competence was significantly associated with reduced HbA1c. Unexpectedly, controlled motivation was associated with lower baseline HbA1c, and autonomous motivation with higher baseline HbA1c, in study II. Although speculative, this may reflect glycemic control that is unlikely to be maintained over time, since controlled motivation is assumed to build weaker behavioral engagement over time, compared to having autonomous maintenance motives (Williams et al., 1996).

Individual differences, both psychological and sociodemographic, may affect treatment response, and improved understanding of these differences could help explain, and possibly reduce, treatment difficulties. The results from study I and II emphasize the importance of individualized care and multifactorial risk factor control in diabetes management, where both support for the emotional management of diabetes and support for weight management may need to be considered. In light of the latest report from the Swedish National Diabetes Registry, showing an increase in the proportion of patients with a BMI indicative of obesity, the need for efforts not only to support glycemic control, but also to focus on support for weight reduction, seems particularly relevant (Eeg-Olofsson et al., 2020).

Patients' perspectives on diabetes management and need for support

Results from study III suggest that there is considerable variation in perceived urgency and distress regarding self-management of diabetes. Not feeling worried about having diabetes was described as influencing the motivation to engage in diabetes management, while feeling too distressed was experienced as a barrier to self-management because of the impact of distress on the individual's emotional wellbeing. Previous studies have observed that T2D has a negative impact on emotional wellbeing, and there has been a growing interest in diabetes distress and how to assess it in diabetes care (Pal et al., 2018; Fisher et al., 2019). However, previous research has only found a modest association between diabetes distress and glycemic control (Schmidt et al., 2018). It is not unlikely that the effect of diabetes distress may be mediated by other factors. Having low distress but lacking in knowledge, competence, or support would reasonably result in little impact on HbA1c values (Skinner et al., 2019). The results from study III acknowledge that, to some individuals, T2D is an emotional burden that could negatively influence the motivation to engage in necessary self-care behaviors. While there is clear evidence that T2D is preventable by changing lifestyle (Uusitupa et al., 2019), initiating and maintaining lifestyle changes is difficult, and this is one of the main challenges in diabetes care. The negative emotional aspects of living with T2D could hamper effective self-management, and this needs to be addressed in diabetes care. As noted by Pal et al. (2018), solely focusing on information provision and the medical management of T2D may not adequately meet the needs of this patient group.

Participants' descriptions of how they would use a web-based intervention to support lifestyle changes mainly revolved around support to feel positive about the changes (e.g., by receiving encouragement), and a supportive structure to make change happen (e.g., access to reliable information, and support to facilitate goal setting). Participants' feedback regarding self-affirmation in the context of diabetes self-management was overall encouraging, suggesting that further efforts to support patient autonomy and help patients connect diabetes management to everyday life, could be a fruitful addition to the medical management of T2D.

Evaluation of a web-based intervention encouraging lifestyle change to improve glycemic control

Results from study IV showed improved and sustained glycemic control in participants using the web-based intervention. The intervention was designed to promote self-reflection and encourage personalisation of lifestyle changes. In line with a patient empowerment approach, the tool provides health- related information to support patients to make informed decisions, as well as supporting them towards self-awareness about their own values, needs, and goals regarding diabetes management. While knowledge about diabetes and treatment options is often emphasized in diabetes care, an understanding of patients' values, needs, goals, and aspirations in relation to diabetes management tends to be overlooked. Although increased knowledge about diabetes and diabetes management is important, knowledge alone is not consistently related to improved glycemic control (Norris et al., 2001). Korhonen et al. (1983) conclude that –

> "… the effects of educational programs are of limited value if they do not lead to permanent changes in attitudes and motivation, which are critical factors affecting long-term diabetic control." (p. 256)

Findings from study IV suggest that using self-affirmation could complement a more traditional approach to diabetes education by focusing on patients' own values, through the simple task of patients writing reflective questions to themselves. From a clinical point of view, there have been promising studies on the use of Acceptance and Commitment Therapy (ACT) to support diabetes self-management, indicating that a focus on clarification of values and personal goals may be a useful addition to the medical care of T2D (Shayeghian et al., 2016).

Results from study IV showed that the metabolic improvements were sustained over time. By contrast, previous studies have reported a declining effect of lifestyle programs after 6 months (Kebede et al., 2018; Shan et al., 2019; Pal et al., 2013). According to the review of behavior change theories by Kwasnicka et al. (2016), behaviors that are perceived as personally relevant and as in line with the beliefs a person has about him or herself are more likely to be maintained. It is possible that the results regarding the effect of the lifestyle tool reflect continuous performance of behaviors that is beneficial for glycemic control. Supporting sustained patient behavioral change is a cornerstone in T2D treatment (Inzucchi et al., 2014). Previous research has identified important characteristics of web-based interventions effective at promoting behavior change, including the use of theory, the inclusion of behavior change theory, and the mode of delivery (Webb et al., 2010). Interventions that have a theoretical basis and incorporate several behavior change techniques tend to have a larger effect on behavior, as do interventions that adopt some kind of personal contact via email or text messages. In order to capture the complexity of health behavior change, the lifestyle tool was developed based a broad theoretical framework, rather than relying on the often inaccurate notion that "one size fits all." Although the tool does not include personal contact, patients can use it to formulate personally relevant questions to discuss with their health care provider.

Individuals with MOD had a pronounced effect even with less frequent use of the tool, opening up for lifestyle interventions to be personalized based on individual pathophysiology, e.g., using a BMI cutoff. To our knowledge, no previous studies have analysed how individual pathophysiology influences the response to a lifestyle intervention.

The cost-effectiveness modeling of the lifestyle tool further showed that the intervention would save costs by resulting in improved risk factor control, particularly regarding risk factors for macrovascular and microvascular complications. The tool can therefore be an important complement to existing treatment, not least in low-income settings. A scalable tool also has the potential of reach and accessibility, which could fill a gap that has hitherto been unfilled (Chatterjee et al., 2018).

Methodological considerations

The results of this thesis should be considered in light of several limitations and strengths. The observational study design of studies I and II limits any conclusion to be drawn about causality of effects. Although efforts were made to control for potential confounding factors, there is always a possibility of residual confounding. When discussing study I and II, the lack of adjustment for relevant health behaviors was acknowledged. However, health behaviors could also be considered as potential mediators rather than confounders, at least in study I. Further, in study I, no adjustment was made for treatment change, such as change in medication. Since treatment change is more common in groups with high HbA1c variability, adjustment for this would have added to the results.

Selective participation may be an issue when recruiting study participants, and could result in a healthier sample compared to the source population. This was discussed in study I, where participants had relatively good glycemic control, potentially limiting the generalizability of the results. The use of the ANDIS cohort for recruitment of participants did, however, provide a broad foundation for recruitment of participants, since the registry includes all new cases of diabetes in southern Sweden. The comprehensive data collection of the registry also made it possible, in study IV, to use a matched control group for comparison.

In study II, the translated Swedish versions of the questionnaires were not validated, and results should therefore be considered with caution. The original, non-translated, questionnaires were, however, validated. The internal consistency of the questionnaires was examined using Cronbach's alpha, which showed an acceptable level of reliability for all scales used in the study.

In study III, the data collection and analysis were conducted by one person. Since much of qualitative analysis is concerned with interpretation, including several analysts in this process could have increased the credibility of the findings, although efforts were made to consolidate trustworthiness of the research, e.g., by documentation of the process using case report forms for the study visits, recording and transcribing all interviews, and continuously documenting themes as they were generated during the analysis. The study participants in study III were sampled based on the principles of maximum variation sampling, and the study context in which the sampling was carried out was described in order to enable a transferability judgement. Although the sample was considered diverse regarding age, diabetes duration, treatment, and HbA1c, it is still possible that the findings are not applicable to other contexts.

In study IV, no adjustment was made for multiple comparisons. The wait list control condition was complemented by comparisons with matched controls, in order to reduce potential expectancy artefacts, such as changed motivation in individuals randomized to wait. Randomization to wait list instead of randomization to usual care was used to reduce the risk of discontinuation. However, the number of participants randomized and lost to follow-up was relatively high, limiting the generalizability of the results.

The model used in study IV to evaluate cost-effectiveness was based on a number of assumptions, and results are therefore only indicative of general trends. In this kind of model, simulations are common in diabetes interventions as the time horizon of most trials is too short to cover expected benefits.

Conclusion

Male gender, obesity, and a negative appraisal of diabetes are all factors associated with greater HbA1c variability in T2D, possibly making these patients more vulnerable to future diabetes complications. A negative appraisal of diabetes can indicate a negative emotional impact of living with T2D, stressing the need for both assessment and treatment of diabetes-related distress. Individuals with T2D may also experience a gap between recommended lifestyle changes and their preferred way of living, which can negatively influence motivation to lifestyle changes.

Patients with T2D report a need for a lifestyle support that would provide encouragement and reliable information, and help them to prioritize, in order to increase motivation, reduce diabetes-related distress, and be of practical help in making health-beneficial lifestyle changes. An online lifestyle tool based on the principles of self-affirmation and MI can be used to improve glycemic control in individuals with T2D, and may be especially effective in a subgroup of patients with obesity and insulin resistance. The tool has the potential to complement existing care and may be directed towards those patients who would benefit the most.

Future research

Although deleterious effects of HbA1c variability on health have been proposed, more studies are needed to confirm it as an independent risk factor for diabetes complications. Future studies should also explore differences in diabetes self-care behaviors in the identified groups with less stable glycemic control, to further examine the behavioral influences on HbA1c variability. From a patient perspective, there seems to be a gap between recommendations regarding diabetes self-care activities and the reality of some patients. Needs assessments of the patient group should continuously be prioritized in research on support for diabetes self-management, in order to ensure that patient-perceived problems are addressed. Qualitative studies exploring patients' experiences of web-based interventions could further inform future considerations regarding new solutions to support diabetes self-management. The self-reflective element of the lifestyle tool as a suggested pathway to improved glycemic control deserves further examination, and could provide insights into how health information to promote lifestyle changes is best delivered to the patient group. The pronounced effect of the lifestyle tool in the MOD subgroup needs to be further examined, and could provide additional knowledge about the value of individualizing self-management support.

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Stability and change

Emelia Mellergård is a licenced clinical psychologist, specializing in health psychology. This thesis examines patient factors associated with glycemic control and patients' experiences of living with type 2 diabetes, and evaluates the effect of a new, self-managed lifestyle support to enhance glycemic control.

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