

RESEARCH ARTICLE

## Impatto delle tecnologie distali, Telehealth e mHealth, sul self management del diabete di tipo 1: una revisione narrativa

### Distal technologies impact, Telehealth and mHealth, on type 1 diabetes self-management: a narrative review

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#### ABSTRACT

**Aim** To evaluate the possible influences of new technologies on quality of life, disease and complications management (self-management) in children, teenagers and young adults with type 1 diabetes mellitus (T1DM).

**Research design** Narrative review.

**Materials and methods** We performed a research through scientific/medical database: PubMed, Cinahl, The Cochrane Library, Proquest Central, Phych INFO and UpToDate, applying the following filters: studies in humans, English language and most recent publication (from 2007 to 2017). Only those responding to the following selection criteria have been selected:

1. Quantitative studies.
2. Use of quantitative evaluation tools, monitoring quality of life and self-management.
3. Reference population of age group less than 65 years old.
4. Focus on usefulness, satisfaction and technologies influence on quality of life and disease self-management of T1DM subjects (outcomes).

**Results** Among the selected articles, only 7 were fitting the inclusion criteria of this review. Overall, despite some studies did not show significant differences in quality of life, results showed an increased frequency in Self Monitoring Blood Glucose (SMBG) and an improved metabolic control with the use of new technologies, especially in young teenagers with T1DM.

**Conclusion** The different studies showed the potential advantages and the overall feasibility of using new apps on mobile technologies, that appear to be mostly effective in young teenagers affected by chronic disease, such as T1DM. These data suggest to identify new effective and ac-



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ceptable technologies that may be useful to enhance care adherence and impact on quality of life in young T1DM patients.

**Key words** type 1 diabetes mellitus; self-management; SMBG (self-monitoring of blood glucose); mobile technologies; telemedicine; quality of life.

## RIASSUNTO

**Obiettivo** Valutare l'utilizzo delle nuove tecnologie sulla qualità di vita e la gestione della malattia (autogestione) e delle sue complicanze in bambini, adolescenti e giovani adulti affetti da diabete mellito di tipo 1.

**Disegno di ricerca** Revisione narrativa.

**Materiali e metodi** È stata condotta una ricerca attraverso i database medico / scientifici: PubMed, Cinahl, The Cochrane Library, Proquest Central, PhychINFO e UpToDate. Tra gli articoli reperiti, secondo i filtri di specie umana (Humans), lingua inglese (English language) e recente pubblicazione entro gli ultimi 10 anni (from 2007 to 2017), sono stati selezionati solo quelli corrispondenti ai seguenti criteri di selezione: 1. Studi quantitativi, 2. Utilizzo di strumenti quantitativi di valutazione e monitoraggio qualità di vita e autogestione, 3. Popolazione di riferimento di fascia di età inferiore a 65aa, 4. Focus dello studio sono utilità, soddisfazione e influenza delle tecnologie sulla qualità di vita e autogestione della malattia dei soggetti affetti da diabete di tipo 1 (outcomes).

**Risultati** Sono stati selezionati per questo studio un totale di 7 articoli. Nonostante alcuni studi non mostrino differenze significative sulla qualità di vita con l'uso di nuove tecnologie, in generale i risultati indicano un miglioramento significativo nel controllo glicemico dei pazienti giovani adulti affetti da diabete mellito di tipo 1, limitando le tempistiche dei controlli medico-assistenziali e con costi complessivamente più bassi.

**Conclusioni** I diversi studi mostrano la fattibilità di avvalersi di nuove applicazioni su tecnologie mobili utili soprattutto in età adolescenziale alla gestione della malattia cronica, dimostrando come l'uso di nuovi strumenti si associ ad un aumento della frequenza dei monitoraggi glicemici migliorando di conseguenza il controllo metabolico. Pertanto, identificare nuove tecnologie efficaci e accettabili migliora l'adesione alla cura del diabete e l'impatto sulla qualità di vita.

**Parole chiave** diabete di tipo 1; autogestione; tecnologie mobili; telemedicina; qualità di vita.

## BACKGROUND

Type 1 diabetes mellitus (T1DM) is the most common and severe childhood metabolic disorder. Its incidence is constantly increasing all over the world<sup>(1)</sup>. Diabetes is a complex chronic disease that can result in serious acute and chronic complications. The adherence to SMBG in the contest of disease self-management can be very complex and demanding mostly for children and teenagers<sup>(2)</sup>. Since adolescence is considered age of transition and very difficult time in life, according to Di Bartolo and coauthors, it is essential to promote therapeutic education through modern communication systems and to motivate young populations in employing technologies to self-manage diabetes<sup>(3)</sup>.

Specific communication systems in diabetes care are becoming more and more refined and, as part of "Telemedicine" programs, they allow patients and physicians to exchange clinical data and therapeutic advice, underlining the potential advantages of new technologies in treatment, self-management and quality of life in young T1DM patients<sup>(3)</sup>.

New smartphone, thanks to applications as insulin bolus calculator and blood glucose measurer, can help children and teenagers affected by T1DM in complex insulin regulation and self-management. Even though more accurate studies are needed, mobile technologies have the potential to improve both self-care and quality of life<sup>(2)</sup>.

New communication modalities are entering the daily routine and are increasingly used as educational systems for patients affected by chronic disease. Sometimes these tools have become even more important and useful than direct contact, because they allow to interact with people, for example teenagers, who otherwise have adopted refusal attitudes and denial about rules. Therefore, it is pivotal to know and examine all technological innovations in order to apply the most suitable one to a specific patient and context<sup>(3)</sup>. The impact of such technologies on quality of life has also to be considered, in fact it is an increasingly recognized variable that affects psychosocial health in young T1DM patients affected<sup>(1)</sup>. Diabetes management is an application area where mobile devices could improve quality of life for people living with chronic diseases<sup>(4)</sup>, especially mobile phones, that for they wide use, can potentially help diabetes daily management through the creation of an active interaction between patients and health-

care providers<sup>(5)</sup>. Thus, compared to the first-generation mobile phones, today smartphones and tablet PC offer a wide range of functions, even in the medical field, where several available applications support disease management, promoting health and well-being awareness<sup>(6)</sup>.

At this regard, Arnhold's et al. (2014) showed that numerous applications are already available to help both type 1 and type 2 diabetes management, with the number of health-related applications increasing up to 31.000 in 2013<sup>(6)</sup>. Some studies present a diabetes mobile applications in-depth analysis, which shows in the first place that personalized education is only in some applications<sup>(4)</sup>.

However, in despite of the considerable amount of diabetes mobile applications currently available, most of these offer only a limited number of personalized features. In fact, it is increasingly difficult for users to find an application that suits their needs<sup>(6)</sup>. The ideal one would be a multifunctional application that could simultaneously inform and advice patients through scientific documentation, reminder and counseling functions, an application that may be particularly useful in recently diagnosed T1DM patients. In addition, patients and healthcare providers should be directly involved during the application development to address practical usage, revealing issue needs for their diabetic followers<sup>(6)</sup>.

Another issue highlighted by Baron's et al. (2012) is the importance of remote data recording and monitoring, also called mobile telemonitoring (mobile Health)<sup>(7)</sup>. Thanks to the development of mobile devices and wireless technologies, patients could transmit real time data, at any time and anywhere, which may help in the management of chronic diseases, that require an intensive daily monitoring<sup>(6)</sup>. Accordingly, many studies show that glucose values measured in real time automatic transmission from the measuring device to mobile device is an important driver to promote ease of use and consequently patient's adherence<sup>(6)</sup>. Furthermore, some manufacturers already offer glucose meters that allow measuring blood glucose values in real time, with the transmission via Bluetooth to a mobile device, simplifying documentation process for the patient and, at the same time, increasing reliability of the entered data and the subsequent analysis.

However, wireless technology use in health care has been primarily evaluated as a telemedicine tool and patient orientation is still under development<sup>(8)</sup>.

These new monitoring methods (such as applications or website that help monitor food intake, glucose levels, controls and other significant parameters) in

T1DM management have been well accepted ensuring good decision-making processes, efficiency and adherence to treatment<sup>(9)</sup>.

Giménez-Perez's et al. (2002) study assessed how the use of internet affects knowledge and well-being of the patient, stating that internet advent will probably change the way healthcare will be carried out. Currently, its impact is particularly compromised by access rate and internet use for health purpose, but due to their high rate of ownership and use, mobile phones will be an important promise as a tool in health communication technologies<sup>(8)</sup>. Among the many studies examined, in this regard, a meta-analysis by Liang's et al. (2011) has shown that mobile phone intervention methods for diabetes treatment have led to significant improvements in glycemic control and self-management<sup>(5)</sup>. Mobile devices use, data recording and monitoring could be also the key factor to increase patients' awareness and motivation in diabetes management<sup>(7)</sup>. In this regard, Guo's et al. (2014) study demonstrated that self-management can positively influence metabolic control and quality of life.

Nurses have a key role in promoting disease self-management and improving health outcomes in young people affected by T1DM, taking responsibility to be health educators and providing self-management constant support, a very important role in helping young people achieve better and more effective treatment plans<sup>(1)</sup>.

The aim of this narrative review is to evaluate current literature on the role of new technologies on quality of life, disease management (self-management) and diabetes complications in children, teenagers and young adults affected by T1DM.

## MATERIALS AND METHODS

Literature research was conducted via PICO method and the use of predefined and specific keywords within the databases. During the research, abbreviations related to the topic were considered, such as SMBG (Self-monitoring blood glucose), HbA1c (hemoglobin glycosylated), Telemedicine and mHealth (MobileHealth).

### PICO

- P (population) = Patient affected by type 1 diabetes.
- I (intervention) = Technologies evaluation for SMBG and management.
- C (comparison) = Traditional care.
- O (outcomes) = Improvement in self-management and quality of life.

Databases research guided by different keywords combinations identified scientific articles abstracts that were relevant based on:

- Comparison between new mobile technologies (smartphones, tablet, PC, app, software) and glycemic measuring standard method (SMBG).
- New technology impact on glycemic monitoring, type 1 diabetes management, chronic disease self-management and quality of life.

Articles were selected according to these criteria:

- Quantitative studies.
- Use of quantitative tools to evaluate and monitor quality of life and self-management.
- Reference population of age group less than 65 years old.
- Study focus on utility, satisfaction and technologies influence on quality of life and disease self-management of those affected by type 1 diabetes mellitus (outcomes).

**Table 1 |** Studies selected with search string:

- 1) Type 1 diabetes AND self-management AND smartphone application AND mobile health.
- 2) Ttype 1 diabetes AND self-management AND telemedicine.
- 3) Ttype 1 diabetes AND telemedicine AND software.

DATABASES	SEARCH STRING AND FILTERS	ARTICLES FOUND/ SE-LECTED	REFERENCES	LINK
PubMed	<p><i>Key words:</i> Type 1 diabetes AND Self-management AND Smartphone applica-tion AND Mobile Health</p> <p><i>Publications date:</i> From 2007 to 2017</p> <p><i>Species:</i> Humans</p> <p><i>Languages:</i> English</p>	8/1	<p><b>Diabetes Self-Management Smart-phone Application for Adults with Type 1 Diabetes: Randomized Con-trolled Trial</b> Morvenna Kirwan, Carmeel Van-delanotte, Andrew Fenning, Mitch J Duncan. J Med Internet Res 15(11):e235, 2013.</p>	<a href="https://www-ncbi-nlm-nih-gov.ezproxy.unibo.it/pubmed/24225149">https://www-ncbi-nlm-nih-gov.ezproxy.unibo.it/pubmed/24225149</a>
Cinhal		0/0		
PsyINFO		0/0		
The Cochrane Library		2/0		
UpToDate		10/0		
ProQuest Central		39/0		
Pubmed	<p><i>Key words:</i> Type 1 diabetes AND Self -management AND Telemedicine</p> <p><i>Publications date:</i> From 2007 to 2017</p> <p><i>Species:</i> Humans</p> <p><i>Languages:</i> English</p>	63/1	<p><b>Young patients with type 1 diabetes poorly controlled and poorly com-pliant with self-monitoring of blood glucose: can technology help? Re-sults of the i-NewTrend randomized clinical trial</b> Paolo Di Bartolo, Antonio Nicolucci, Valentino Cherubini, Diario Iafusco, Marco Scardapane, Maria Chiara Rossi. Acta Diabetol 54:393-402 Italia, 2017</p>	<a href="https://www-ncbi-nlm-nih-gov.ezproxy.unibo.it/pubmed/28138788">https://www-ncbi-nlm-nih-gov.ezproxy.unibo.it/pubmed/28138788</a>

Cinhal		15/0		
PsycINFO		12/0		
The Cochrane Library		2/0		
UpToDate		30/0		
ProQuest Central		395/0		
PubMed	<p><i>Key words:</i> Type 1 diabetes AND Telemedicine AND Software</p> <p><i>Publications date:</i> From 2007 to 2017</p> <p><i>Species:</i> Humans</p> <p><i>Languages:</i> English</p>	26/1	<p><b>The Diabeo Software Enabling Individualized Insulin Dose Adjustments Combined With Telemedicine Support Improves HbA1c in Poorly Controlled Type 1 Diabetic Patients</b> Guillaume Charpentier, Pierre-Yves Benhamou, Dured Dardari, Annie Clergeot, Sylvia Franc, Pauline Schaepe-lyncck-Belicar, Bogdan Catargi, Vincent Melki, Lucy Chaillous, Anne Farret, Jean-Luc Bosson, Alfred Penforis. <i>Diabetes Care</i> 34:533-539, 2011.</p>	<p><a href="https://www.ncbi.nlm.nih.gov.ezproxy.unibo.it/pubmed/21266648">https://www.ncbi.nlm.nih.gov.ezproxy.unibo.it/pubmed/21266648</a></p>
Cinhal		2/0		
PsycINFO		2/0		
The Cochrane Library		9/0		
UpToDate		10/0		
ProQuest Central		396/0		

**Table 2 |** Studies selected with search strings:

- 1) Type 1 diabetes AND self-management AND quality of life AND mobile application.
- 2) Type 1 diabetes AND self-management AND telemedicine AND quality of life.

DATABASES	SEARCH STRING AND FILTERS	ARTICLES FOUND AND SELECTED	REFERENCES	LINK
PubMed	<p><i>Key words:</i> Type 1 diabetes AND Self-management AND Quality of life AND Mobile application</p> <p><i>Publications date:</i> From 2007 to 2017</p> <p><i>Species:</i> Humans</p> <p><i>Languages:</i> English</p>	4/1	<p><b>The Effects of a Mobile Phone Application on Quality of Life in Patients With Type 1 Diabetes Mellitus: A Randomized Controlled Trial</b> Iefke Drion, Loes R. Pameijer, Peter R. van Dijk, Klaas H. Groenier, Nanne Kleefstra, Henk J. G. Bilo. <i>Journal of Diabetes Science and Technology</i> 9:1086-1091, 2015.</p>	<p><a href="https://www.ncbi.nlm.nih.gov.ezproxy.unibo.it/pubmed/2596341">https://www.ncbi.nlm.nih.gov.ezproxy.unibo.it/pubmed/2596341</a></p>
Cinhal		0/0		
PsycINFO		0/0		
The Cochrane Library		1/0		
UpToDate		20/0		

ProQuest Central		460/0		
ProQuest Central	<p><b>Key words:</b> Type 1 diabetes AND Self management AND Telemedicine AND Quality of life</p> <p><b>Publications date:</b> From 2000 to 2017</p> <p><b>Search Fields:</b> Title/Abstract</p> <p><b>Species:</b> Humans</p> <p><b>Languages:</b> English</p>	167/1	<p><b>Diabetes Interactive Diary: A New Telemedicine System Enabling Flexible Diet and Insulin Therapy While Improving Quality of Life</b> Maria C. Rossi, Antonio Nicolucci, Paolo Di Bartolo, Daniela Bruttomesso, Angela Girelli, Francisco J. Ampudia, David Kerr, Antonio Ceriello, Carmen De La Questa Mayor, Fabio Pellegrini, David Horwitz, Giacomo Vespasiani. Diabetes Care 33:109–115, 2010.</p>	<p><a href="http://search.proquest.com.ezproxy.unibo.it/central/docview/223039305/3C-40CB2B8370496BP-Q/3?accountid=9652">http://search.proquest.com.ezproxy.unibo.it/central/docview/223039305/3C-40CB2B8370496BP-Q/3?accountid=9652</a></p>
Cinhal		0/0		
PsyINFO		1/0		
The Cochrane Library		0/0		
UpToDate		10/0		
PubMed		0/0		

**Table 3** | Studies related to selected research (references).

It shows selected articles among the mentioned bibliography of Kirwan’s et al. (2013) article.

SELECTED ARTICLES	SEARCH STRING AND FILTERS	ARTICLES FOUND AND SELECTED	REFERENCES	LINK
<p><b>Diabetes Self-Management Smartphone Application for Adults with Type 1 Diabetes: Randomized Controlled Trial.</b> Morvenna Kirwan, Carmeel Vandell-anotte, Andrew Fenning, Mitch J Duncan. J Med Internet Res 15(11):e235, 2013</p>	<p><b>Key words:</b> Type 1 diabetes AND Self-management AND Smartphone AND application AND Mobile Health</p> <p><b>Publications date:</b> From 2007 to 2017</p> <p><b>Search Fields:</b> Title/Abstract</p> <p><b>Species:</b> Humans</p> <p><b>Languages:</b> English</p>	n° 30	<p><b>Feasibility of a Mobile Phone-Based Data Service for Functional Insulin Treatment of Type 1 Diabetes Mellitus Patients.</b> Alexander Kollmann, Michaela Riedl, Peter Kastner, Guenter Schreier, Bernard Ludvikj. Med Internet Res;9(5):e36, 2007</p>	<p><a href="https://www.ncbi.nlm.nih.gov.ezproxy.unibo.it/pubmed/?term=Feasibility+of+a+Mobile+Phone%E2%80%93Based+Data+Service+for+Functional+Insulin+Treatment+of+Type+1+Diabetes+Mellitus+Patients">https://www.ncbi.nlm.nih.gov.ezproxy.unibo.it/pubmed/?term=Feasibility+of+a+Mobile+Phone%E2%80%93Based+Data+Service+for+Functional+Insulin+Treatment+of+Type+1+Diabetes+Mellitus+Patients</a></p>
		n° 20	<p><b>Design of an mHealth App for the Self-management of Adolescent Type 1 Diabetes: A Pilot Study</b> Joseph A Cafazzo, Mark Casselman, Nathaniel Hamming, Debra K, Katzman, Mark R Palmert J Med Internet Res 14(3):e70, 2012.</p>	<p><a href="http://web.a.ebscohost.com.ezproxy.unibo.it/ehost/detail/detail?sid=1f1b8f38-4fa1-431a-9104-6fbc54796502%40sesessionmgr4009&amp;vid=0&amp;hid=4212&amp;bdata=jmxhbm9aXQmc2l0ZT1laG9zdC1saX-ZlJnNjb3BIPXNpdGU%3d#AN=10448-8871&amp;db=ccm">http://web.a.ebscohost.com.ezproxy.unibo.it/ehost/detail/detail?sid=1f1b8f38-4fa1-431a-9104-6fbc54796502%40sesessionmgr4009&amp;vid=0&amp;hid=4212&amp;bdata=jmxhbm9aXQmc2l0ZT1laG9zdC1saX-ZlJnNjb3BIPXNpdGU%3d#AN=10448-8871&amp;db=ccm</a></p>

**RESULTS**

Because of the widespread diffusion of diabetes, the impact of technology on glycemic control and diabetes-related quality of life has been studied in different parts of the world. Studies dealing with the use of new technologies in helping the disease management and their influence on quality of life are mainly carried out in Europe (Italy and France), America (Canada) and Australia. In particular, 5 out of 7 are RCT (randomized controlled trials) and the remaining 2 are pilot studies. The different studies have been published over the years, from 2007 until the early months of 2017. In our current review we selected articles from J Med Internet Res (3 studies), Diabetes Care (2 studies), Acta Diabetol and the Journal of Diabetes Science and Technology with one article respectively. All the articles taken into consideration showed defined research design (RCT) that allows to evaluate how new technological systems use, compared with traditional glycemic control only in 5 studies, influence self-monitoring, compliance and quality of life in children, teenagers and young adults affected by T1DM. The remaining two references are pilot studies. Sample size was not homogeneous among the different selected studies, ranging from a minimum of 10 patients<sup>(10)</sup> to a maximum of 182 patients<sup>(11)</sup>. With regard to patients type, only young patients under 65 years old affected by T1DM were taken into consideration, including adolescents. Outcomes evaluation times also differ among the studies: from 12 weeks<sup>(12)</sup> to more than 18 months<sup>(11)</sup>.

Examined technologies are quite heterogeneous, ranging from telemedicine such as smartphones, software, telephones applications for glycemic monitoring values to new monitoring systems. Evaluation scales used to examine their impact on self-management and quality of life are DES-SF (Diabetes Empowerment Questionnaire), WHO-DTSQ (World Health Organization-Diabetes Treatment Satisfaction Questionnaire), PAID (Problem Areas in Diabetes questionnaire), SDSCA (the Summary of Diabetes Self-Care Activities), SF-36 health surgery, RAND-36 health surgery, DQOL (Diabetes Quality of Life), DQOL-Y (Diabetes Quality of Life for Youth), AddQOL (Audit of diabetes-dependent Quality of Life) and DSQOLS (Diabetes Specific Quality of Life Scale).

Summarized outcomes are:

- mobile and non-mobile technologies utility for T1DM monitoring and management
- influence on quality of life and satisfaction in treatment and/or in device
- glycemic values improvement such as HbA1c.

**DISCUSSION**

Use of new technologies influences quality of life and disease management in adolescents and young adults affected by T1DM. Over time, technologies have increasingly evolved, improved and integrated in patients treatment plans. Despite the lack of large studies, results indicate a positive trend on chronic disease self-management

**Table 4** | Detailed description of each study.

STUDY	STUDYTYPE	PURPOSE	N° PARTICIPANTS	EVALUATION TIME AND OUTCOMES	PRI-MARYAIM	SECON-DARYAIM	QUANTI-TATIVE TOOLS	TECHNOLO-GICALTO-OLS
Di Bartolo et al. (2017)	RCT	Compare new tele-medicine system called iBG-Star and DMAP with traditional glycemic control in teenagers and young adult affected by type 1 diabetes.	92 group A (iBGStar system) + 90 control group  182 totals	3-6 months experimental phase and 12 months post-trial observational phase.	Evaluate how tele-medicine system influences self-monitoring measuring and analyzing HbA1C value.	Evaluate this technology influence in compliance and quality of life.	1. Audit of Diabetes-dependent quality of life (AD-DQol) 2. Diabetes Quality of Life (DQOL) 3. Visual analogue scale (VAS)	1.iBGStar telemedicine system

Drion et al. (2015)	RCT	Investigate the use of mobile application (DBEES) as a diabetes digital diary in patients affected by type 1 diabetes with traditional paper diary.	31 intervention group (digital diary uses DBEES) + 32 control group (paper diary)  63 totals	3 months	Evaluate two carbohydrates calculation methods influence on quality of life.	Evaluate mobile application usability, HbA1c values, self-monitoring frequency.	<ol style="list-style-type: none"> <li>1. RAND-36 health survey</li> <li>2. Problem Areas in Diabetes questionnaire (PAID)</li> <li>3. SUS for application usability evaluation</li> </ol>	<ol style="list-style-type: none"> <li>1. DBEES mobile phone application as a diabetes diary</li> </ol>
Kirwan et al. (2013)	RCT	Examine the effectiveness of a smartphone application freely available in combination with a feedback system of text message sent by an expert (diabetes certified educator) in young patients affected by type 1 diabetes.	36 intervention group (smartphone application use) + 36 control group (glucometer use)  72 totals	9 months, regular SMBG every 3 months	Evaluate HbA1c levels variation following a glycemic control increase	Evaluate self-efficacy related to diabetes management, activity and self-care, quality of life.	<ol style="list-style-type: none"> <li>1. Diabetes-related psychosocial self-efficacy (DES-SF)</li> <li>2. Summary of Diabetes Self-care Activities (SDSCA)</li> <li>3. Diabetes quality of life (DQOL)</li> </ol>	<ol style="list-style-type: none"> <li>1. Glucose Buddysmartphone application</li> </ol>
Cafazzo et al. (2012)	Pilot study	Design and develop a mHealth (mobile health) pilot intervention for type 1 diabetes management in teenagers using mobile applications applied to iPhone phones thanks to a glucometer fitted with a Bluetooth adapter	20 totals aged between 12-16yo	12 weeks	Daily average frequency evaluation of measurements and glucose values and HbA1c variations through mobile phone or ipod touch use	Evaluation of self-efficacy and adherence to treatment, quality of life and family responsibility in diabetes management	<ol style="list-style-type: none"> <li>1. Self-care Inventory (Self-care 14)</li> <li>2. Diabetes Family Responsibility Questionnaire</li> <li>3. Diabetes Quality of life for youth (DQOL-Y)</li> </ol>	<ol style="list-style-type: none"> <li>1. Mobile application associated to a LifeScan glucometer with a Bluetooth adapter</li> </ol>



Guillaume et al. (2011)	RCT	Demonstrate that Diabeo software can calculate the right dose of insulin bolus, supported by a telemedicine system, significantly improving HbA1C values in poorly controlled type 1 diabetic patients	61 group G1 + 60 group G2 + 59 group G3  180 totals with age>18 yo	17 months with basal SMBG every 3 months and at the study end	Evaluate HbA1c value variations	Evaluate change in glycemic monitoring frequency (SMBG), in quality of life changes and satisfaction time spent in visits or telecommunications	1. Diabetes quality of life (DQOL) 2. Diabetes health profile questionnaire	1. Software called Diabeo installed in smartphone, insulin bolus automatic calculator which data are directly transmit to the doctor
Rossi et al. (2010)	RCT	Compare diabetes interactive diary (DID) use and standard carbohydrate count	67 intervention group (DID use) + 63 control group  130 totals with age>18 yo	6 months	Evaluate DID use in glycemic control improvement in shorter time and easier approach than carbohydrate counting standard method	Changes in fasting glucose levels (FBG), body weight, lipidic profile, blood pressure and quality of life evaluation treatment satisfaction	1. Health Survey-SF-36 2. World Health Organization – Diabetes Treatment Satisfaction Questionnaire (WHO-DTSQ)	1. DID interactive diary carbohydrate-bolus insulin automatic calculator to install in telephone
Kolmann et al. (2007)	Pilot study	Evaluate the feasibility and user acceptance of a mobile service able to assist patients in intensive insulin DM1 treatment reporting data to a web portal	10 totals aged between 18–80 yo affected by type 1 diabetes	3 months	Record as many possible logins showing a high acceptance rate and a use with positive feedbacks	Evaluate new data collection device use monitoring HbA1C	1. Device satisfaction evaluation questionnaire	1. Software application called Diab-Memory

and glycemic control, without highlighting any significant quality of life variation. The analysis encompassed a period of ten years, from 2007<sup>(10)</sup> to 2017<sup>(11)</sup>, from simple reminder softwares to a self-management tool, and then up to sophisticated automatic calculator softwares of carbohydrate and insulin bolus, such as Diabeo system<sup>(13)</sup> and DID system<sup>(14)</sup>.

Mobile phone and wireless technology have become absolute protagonists since 2007 thanks to mobile Diab-Memory application<sup>(10)</sup>, then evolved and improved in the following years through new mobile applications integration, providing more individualized health assistance. Communication technology, also called telemedicine, allows to monitor and transmit in real time-

blood glucose values and increases contact frequency and direct exchange between patients and healthcare professionals.

Among the seven selected articles, Kirwan et al. highlighted the potential of smartphones through applications as Glucose Buddy, which uses a text-message feedback system sent from an expert in order to improve glycemic control and consequently reduce HbA1c values<sup>(45)</sup>.

One of the most relevant studies conducted by an Italian experts group in 2017 demonstrated how telemedicine systems can encourage teenagers to adhere to treatment using new devices which double daily measurements frequency of glucose values, thereby reducing HbA1c values<sup>(41)</sup>. Technologically advanced solutions can be an option to motivate patients to regularly check blood glucose values, especially for young teenagers particularly inclined to technology. Adolescence represents a peculiar, highly delicate and susceptible time of personal development: teenagers begin to acquire their independence and autonomy from the family, but when the diagnosis approaches, patients show their psychosocial vulnerability, especially at the end of the “honeymoon” period and when treatments become more intense<sup>(46)</sup>. Family conflicts are very frequent, generated around treatment needs in chronic disease, especially at its onset, thereby interfering with treatment outcomes. Di Bartolo and his team conducted their studies in a young population with a propensity towards technology. Adapting to patient needs, they searched the most suitable and requested type of patient communication system, because communication has significant psychosocial and social implications<sup>(41)</sup>. Teenagers are inclined to request their autonomy and to grow apart from adults, to hide themselves in the internet world where they search for answers, advices and comparisons through web and mobile world; so it is important to focus on developing great and powerful technologies. Psychosocial impact is significant; it is worth of notice comparing a chat line system and a social network<sup>(3)</sup>, the latter identified less success assuming that teenagers struggling with diabetes do not intend to show themselves, preferring to remain anonymously in chat line microcosm. New communication methods are thus used in health field as an educational system promoting direct contact between patients, professionals and peers, not to deny the disease but to know, understand the most appropriate way of treatment regimens and self-management and to promote long-term

complications prevention. Young patients are open to the unlimited wireless and mobile world, experiencing everything too “automated”, with the risk of reducing patient awareness of his/her health condition. For this reason, the innovative system proposed must be always associated with an educational intervention.

Most of the studies analyzed in this review consider the design and the operativity of mobile applications and software, comparing them to classical SMBG system and evaluating their impact on HbA1c values (self-monitoring); only few studies examine the influence of their use on quality of life and treatment satisfaction.

Among all the analyzed studies only one<sup>(47)</sup> established as primary aim how technology influences quality of life; it is necessary to overcome this limit, because quality of life (QOL) improvement is an important target to evaluate in any study on young populations, because of its close relationships with depression, disease progression, therapeutic adhesion and consequently to mortality<sup>(41)</sup>. Further studies are needed, directed to a larger sample with frequent follow-up in a long-term intervention to demonstrate benefits and harms in using mobile applications on quality of life.

According to examined literature, for each researched outcome (utility, satisfaction, influence), most studies showed a positive response on glycemic control, statistically improving HbA1c values due to increase in therapeutic adhesion. In respect of treatment satisfaction and influence on quality of life, most of telemedicine technologies showed a good treatment satisfaction without underlining specific influences on quality of life. Therefore, impact on quality of life requires further studies with a long-term intervention.

The economic burden remains a significant obstacle to telemedicine system diffusion, due to the fact that proposed devices are not refundable by medical insurance.

A meta-analysis was not performed because quantitative tools of monitoring and evaluating quality of life and self-management were not comparable among the considered studies.

Furthermore, study duration was variable (from a minimum of 12 weeks to a maximum of 18 months), whereas evaluation of quality of life is a parameter that should be measured on a long-term follow-up; thus explaining the lack of significance of the results on QoL of the examined studies.

Telemedicine services support patient in his/her chronic disease self-management. The use of new

technological systems, such as mobile applications and software systems, encourages young population affected by T1DM to adhere to treatments, increase SMBG and monitor the essential values for good disease management such as glucose levels, insulin dosages, related medical aspect, diet type and physical activity. Software applications on mobile phones offer a strong and easy-to-use platform showing a general satisfaction towards innovative treatment, positively affecting quality of life in the long run.

In the last decade, technologies evolved from reminder software to powerful self-management tools such as insulin bolus automatic calculators based on carbohydrates taken values. “DID” system as well as “Diabeo” software are the emblem of the new advanced technologies able to overcome the complex educational requirement and the various difficulties identified in diabetes mellitus management. These devices are successful due to their ability to calculate insulin dose needed in real time, offering constant telemonitoring and immediate transmission of data to medical portal, and the possibility of arranging teleconsultations. Complexity of disease management is reduced, progressively increasing treatment satisfaction, improving some aspects related to quality of life. Thanks to technological systems, direct contact between patients and healthcare providers is improved, reducing healthcare costs.

In the future, more sophisticated mobile applications are needed: for example the “interactive apps”, able to analyze data collected in real time supported by automatic feedback and systematic consultations between patients and healthcare professionals overcoming the multitude of electronic logbook applications useful for glycemic values collection, visualization and reading.

We need to research and develop new approaches and optimize those already existing in order to manage chronic disease in a difficult period of life as adolescence.

The actual health costs of identifying young patients willing to replace the classic face-to-face follow-up with new telemedicine approaches should be also taken into account.

## CONCLUSIONS

Nowadays, smartphones and PCs accompany everyday life they may represent a great resource, especially in chronic diseases management.

Non adherence to SMBG is a common problem in T1DM young patients, increasing the risk of severe cardiovascular, renal, nervous and visual system damage over time. Blood glucose self-monitoring is considered essential routine in these patients to reach an adequate glycemic control, but it represents a significant burden in every-day life.

During adolescence, the intensive self-management required by the disease can put compliance at risk, so it is important to stimulate a therapeutic alliance between young patients and their physicians based on therapeutic and behavioral goals.

Among adolescents, inclination towards new technologies can support them to meet their needs, helping them to improve self-management.

Mobile phone has become the primary communication tool, making it a powerful platform to provide individualized healthcare.

Telemedicine principle, understood as a contemporary information and communication technology, includes different applications and services that use different telecommunication forms such as e-mails, smartphones, wireless tools, web portals etc. becoming an important means to encourage treatment adherence in this patients group.

The different telemedicine systems used have evolved simplifying self-management process more and more, making available data and graphs in real time and everywhere, promoting the close collaboration between patients and healthcare professionals thanks to direct feedback systems.

In conclusion, available data indicate that, in young adult patients affected by T1DM, new technologies promote a significant improvement in glycemic control, without requiring constant physician presence and with overall lower costs than usual care. On the contrary, the impact on QoL was not significant in most of the examined studies. Furthermore, telemedicine use positively influences treatment satisfaction, suggesting the increase in acceptance levels to the complex therapeutic plan required by chronic disease management.

Different studies show the feasibility of using mobile applications, especially in adolescence, demonstrating how the use of new tools is associated with an increase in glycemic monitoring frequency, improving overall the metabolic control.

Identification of new, effective and acceptable technologies is needed in order to improve adherence to diabetes care and a meliorate quality of life of young patients with T1DM.

Smartphone role moves to diabetes care.

## KEY POINTS

New communication methods associated with mobile phones use are dedicated to a young population particularly inclined to new technologies. They become key factors in patients awareness of disease status, and motivation in self-management of a complex disease as diabetes, improving overall glycemic control.

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