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Review

# Exercise related care pathways for people with diabetes: Literature review and expert consensus

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## 1. Introduction

Physical activity (PA), despite being a primal human function, sort of a language allowing neonates to get in touch with the world around them, has been negatively affected by automation for about one century. This contributed to ever increasing cardiovascular event rate due to the epidemics of metabolic diseases including Diabetes Mellitus (DM) and prompted dedicated scientific societies, including Italian ones [1], to issue specific recommendations based on which GPs and specialists should try to promote exercise among their patients.

Nevertheless metabolic effects, athletic performance and acute complication risk in DM people depend on a whole set of variables including type, duration, intensity and timing of exercise, as well as, attained training level and eventually prescribed insulin/secretagogue doses.

This makes any high intensity, long duration exercise programs less easy to cope with than spontaneously occurring PA, so that joint American Diabetes Association and American College of Sports Medicine (ADA/ACSM) Guidelines suggest all patients to be aware of their own conditions and to get more and more trained to adapt recommendations to their specific requirements according to the so-called "trial and error" rule [2].

Such a complex process is expected to disorient both physicians as for exercise prescription and people with DM as for mid-to-long term adherence to exercise programs. To overcome this problem it might be useful to define a dedicated care pathway (CP), i.e. a well recognized method to improve clinical daily practice, organization and patient safety through an accurate design of care processes taking into account available resources within a certain setting. Therefore, based on new evidence in DM pathophysiology, on recent technology advances and on our longstanding experience in the field of diabetes and exercise, we tried to fill a gap in the literature by issuing an exercise-related CP (ERCP) for safe and effective exercise management in people with both T1DM (i.e. type 1 or "insulin dependent" DM) and T2DM (i.e. type 2 or "non insulin dependent" DM), as an opportunity for both physicians and patients to reduce variation and improve outcomes by key evidence-based interventions within individual contexts.

### 1.1. Common ERCP elements for T1DM and T2DM

**The aim of the ERCP** is to define the minimum set of activities required to encourage people with T1DM and T2DM to exercise and assist them during their daily training.

The following sequence has to be taken into account when preparing any ERCP, independently of the type of DM patients suffer from:

1. Screening for chronic complications (electrocardiogram, any signs of diabetic retinopathy, nephropathy and/or neuropathy)
2. Selection
3. Diabetes team willingness to investigate upon, and enhance, patient motivation to exercise and appropriate counseling
4. Evaluation
5. Education on exercise effects expected to influence drug dose requirements and risk for hypoglycemia
6. Personalized therapeutic indications
7. Effective planning of a structured exercise program
8. Realization
9. Verification

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This is schematically represented in Fig. 1.

## 2. T2DM ERCP

### 2.1. Exercise benefits and recommendations

Both physical inactivity (PI) and sedentary behavior (SB) independently predict all cause and cardiovascular mortality, both being highly prevalent in T2DM patients [3], alter metabolism irrespective of common risk factors and time spent on PA [4], reduce lifespan and make quality of life much poorer [5]. In T2DM patients the degree of sarcopenia (muscle waste) associates negatively with usual PA, quality of life and glucose levels and positively with body weight and wrong food habits [6]. Conversely, a significant correlation was found between overall functional capacity and physical/mental determinants of health related quality of life [7]. Moreover, both spontaneous PA and exercise, provide additional benefits to calorie restriction and drugs [8,9] and especially when performed on a regular and high intensity basis, associate with lower all-cause and cardiovascular mortality [10,11].

To fulfill the latter endpoint, as well as, to prevent non alcoholic fatty liver disease and osteoporosis while lowering therapeutic cost/benefit ratio, joint ACSM/ADA guidelines suggest to perform moderate/vigorous intensity PA (i.e. at 50–70% maximal heart rate o MHR) for at least 150 min/week and/or vigorous intensity PA (>70% MHR as interval training) for at least 90 min/week by distributing sessions in such a way to train at least 3 times a week with rest periods never exceeding 2 consecutive days [2,12].

T2DM metabolic control benefits from supervised resistance exercise involving all major muscle groups both *per se* [13] and when combined with endurance training [14,15]. In fact the latter inhibits inflammatory cytokines while, especially when characterized by low volumes and high intensity (HIIT), resistance training prevents sarcopenia by enhancing muscle oxidative capacity [16–18] and promotes both biogenesis and enzymatic activities of muscle cell mitochondria while lowering hypoglycemic event rates [19,20].

It is therefore mandatory to repeatedly perform individually tailored T2DM patient education on possible negative effects including hypoglycemia depending on the time elapsed between drug administration and physical activity. In fact this is relevant especially for people using long acting sulfonylureas, which are at high risk for long lasting, ill-managed and therefore threatening hypoglycemic events. Virtually no such effects are expected and therefore a less strict education protocol is required, instead, for those on insulin sensitizers, like metformin, pioglitazone and acarbose, or on innovative drugs, including incretins o glifozins, whose underlying mechanisms of action tend to keep glucose variability within narrow and safe limits *per se*.

To define a suitable ECRP for T2DM it is necessary to identify actions and responsibilities so that each team member gets a specific role with respect to the patient and to the overall treatment plan and related costs are easier to calculate in advance (see Table 1).

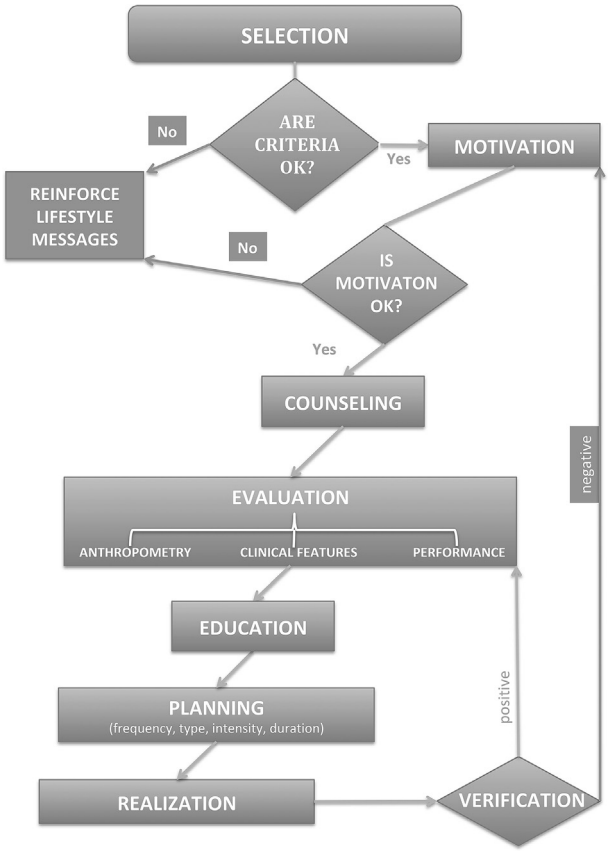



**Fig. 1.** Flow chart of exercise related care pathway for people with DM.

#### 2.1.1. Complication screening

This is the first ineludible phase allowing to identify the best possible exercises patients may be involved in. The process is schematically presented with in Table 2.

#### 2.1.2. Selection

Selecting people appropriately helps prevent overload and poor adherence in the long run and is therefore the best choice. We identified the following selection criteria:

- young enough chronologic or functional age to try and work safely and to get good results by exploiting better physical conditions and higher motivational standards (people with ≤15% risk for fatal cardiovascular events within 10 years according to validated risk engines are selected[1] [21];
- best expected metabolic results in the absence of any drugs (diagnosis ≤24 months before);
- need to postpone treatment intensification for those on poor control.

#### 2.1.3. Motivation

A) **Assessment (i.e. assessing propensity to change**: professionals can use the Patient-centered Assessment & Counseling for Exercise (PACE+) standardized single item 8-choice questionnaire [22] (Table 1) to evaluate attitudes based on stages of change theory [23,24] and design appropriate intervention strategies accordingly (see Tables 3 and 4) [25,26]:
   - **choice 1** – educational model "**getting out of your chair**" (pre-contemplation phase): the subject is not ready to change and it better to just provide a few recommendations;
   - **choices 2–4** - educational model "**planning the first step**" (contemplation phase): the subject is ready to change and therefore it is possible to plan training sessions;

[1] In our country the best risk engine is represented by "CUORE" charts being validated for the Italian population [21].

**Table 1**
T2DM ERCP responsibility assignment matrix.

| NEEDS | RESPONSIBLE PERSONS | ACTIONS |
|---|---|---|
| 1. Complication screening | Diabetes specialist | 1 doctor appointment |
| 2. Selection | Diabetes specialist | 1 doctor appointment |
| **3. Motivation** | | |
| o assessment | Nurse | 1 nurse appointment |
| | Diabetes specialist | 1 doctor appointment |
| o counseling | Adapted Exercise Specialist (AES) | 3 AES appointments |
| **4. Evaluation** | | |
| o anthropometry | Nurse | 1 nurse appointment |
| o metabolic | Diabetes specialist | 1 doctor appointment |
| o performance | AES | 1 AES appointment |
| 5. Education | Diabetes Team/Educator | 3 structured sessions |
| 6. Personalized therapeutic indications | Diabetes specialist | 2 doctor appointments |
| 7. Planning | AES | 1 AES appointment |
| 8. Realization | Regularly spaced supervised sessions | 2 AES appointments |
| **9. Verification** | | |
| o anthropometry | Nurse | 1 nurse appointment |
| o clinical/metabolic | Diabetes specialist | 1 doctor appointment |
| o performance | AES | 1 AES appointment |

**Table 2**
Screening for chronic diabetes complications and exercise recommendations.

| Complication | Finding | How to proceed |
|---|---|---|
| Cardio-vascular disease | o No symptoms? | o No screening is recommended. |
| | o Any symptoms suggestive of CVD? | o Cardiologist evaluation is required. |
| | o Any symptoms suggestive of autonomic neuropathy? | o Specific cardiologist evaluation required. |
| Peripheral Neuropathy | | Periodic foot examination is required. Appropriate footwear is mandatory. |
| Retinopathy | o Background | o All activities are allowed. Yearly check is recommended. |
| | o Moderate non proliferative | o Sports causing sudden blood pressure spikes are not allowed. |
| | o Severe non proliferative or unstable proliferative | o Jumps or sudden head shakes/lowering, or apnea or very intensive efforts are not allowed. |
| | o Intravitreal bleeding | o Stop |
| Nephropathy | o Grades 1 through 3 | o All activities are allowed. |
| | o Grades >3 | o Caution suggests to start training at low intensity and volume. |

**Table 3**
Motivation phases according to the Patient-centered Assessment & Counseling for Exercise (PACE+) questionnaire (modified from PACE Research and Development Team, 1999) [22].

| |
|---|
| 1. I am not engaged in any kind of physical activity and I am not interested in it within next 6 months |
| 2. I am not engaged in any kind of physical activity now but I might start within next 6 months |
| 3. I am trying to start with moderate or intensive physical activity but I do not exercise regularly |
| 4. I am engaged in intensive physical activity less than 3 times a week or in moderate physical activity less than 5 times a week |
| 5. I have been engaged in moderate physical activity for 30 min 5 times a week or more during the last 1–5 months |
| 6. I have been engaged in moderate physical activity for 30 min 5 times a week or more during the last 6 months at least |
| 7. I have been engaged in intense physical activity 3 or more times a week during the last 1–5 months |
| 8. I have been engaged in intense physical activity 3 or more times a week during the last 6 months at least |

**Table 4**
PACE + protocol stage interpretation grid.

| Score | Stage | Counseling target |
|---|---|---|
| 1 | Pre-contemplation (not ready to change yet) | "Getting out of your chair" |
| 2–4 | Contemplation (ready to change) | "Planning the first step" |
| 5–8 | Action (moving) | "Keeping the Pace" |

- **choices 5–8 -** educational model "**keeping the pace**" (action phase): the subject is active already, so it is just necessary to help him pay attention to the objective steadily.

B) Counseling

Performing structured counseling aimed at achieving a shared goal by increasing exercise may be useful for people found in any of the above mentioned phases except for pre-contemplation.

To enhance long term adherence to a personalized, metabolically effective, structured exercise program [19] a diabetes exercise specialist (AES) should be involved in the care team as the only professional certified to tailor exercise sessions to individual patient needs in terms of dosing and sustained motivation [20].

The AES is especially meant for elderly or frail DM patients to prevent cardiovascular and bone/joint complications or counteract them through structured exercise aimed primarily at enhancing flexibility and balance.

Long before planning and prescribing any personalized exercise programs [27] it is necessary to focus on lifestyle habits and conditioning by convincing sedentary patients (especially obese and sarcopenic ones) to reduce their sedentary time by a simple behavioral change like standing up and going for a short walk around the table/room or other very light intensity activity, which in fact has proved beneficial not only for glucose control but also for cardiovascular risk [28].

After a while, light resistance exercise sessions are needed to increase muscle mass/strength and aerobic capacity and decrease body weight.

#### 2.1.4. Evaluation

This phase is aimed at designing a proper personalized structured exercise program) and involves the analysis of anthropometric, clinical, metabolic and performance parameters by different members within the team, as specified in Table 1.

#### 2.1.5. Education

People should be made fully aware of exercise effects expected to influence both drug dose requirements and symptoms of hypoglycemia and educated on how to manage any related emergencies.

#### 2.1.6. Personalized therapeutic indications

These are obviously the result of a thorough clinical evaluation by the specialist and represents the starting point of the whole exercise program.

#### 2.1.7. Planning

Correct exercise doses in terms of rate, type, duration and intensity (METs or volume/week) of exercise have to identified after taking into account individual patient's bio-psycho-social (i.e. phenotype) and clinical features.

#### 2.1.8. Realization

This is a sensitive stage, as properly trained patients are let free to exercise on their own after the initial set of supervised sessions. In fact they might drop-out easily after facing any accidents or social/work troubles, especially when they are middle-age and have to cope with family economic and/or emotion-related responsibilities.

That's why it is mandatory to identify a way to keep in touch with them regularly, e.g. by phone calls and even follow-up visits if needed, the best solution being to plan repeated supervised group exercise sessions well in advance in order to leverage their sense of responsibility since the very beginning and to exploit group exchanges to strengthen the message.

#### 2.1.9. Verification

Waist circumference, BMI, resting heart rate (HR) maximal oxygen consumption ($VO_2$ max), HbA1c, glycemic variability, micro- and macro-vascular complications and global cardiovascular risk scores [21] should be checked regularly against shared targets, possibly at 6 month intervals.

This is relevant for cost benefit-analysis of such an engaging program but represents also an ineludible step to enhance patients' motivation by showing their recent progresses and sharing new targets to be attained through another advanced, deeply moving exercise program.

## 3. T1DM ERCP

Most insulin treated mature-old patients represent a subset of the T2DM population we just described above. So, besides considering the possibility of sudden hypoglycemic event brought about by their spare insulin secretion, it is mandatory to carefully scrutinize them for CVR risk and motivation. Therefore our previous section on T2DM ECRP meets most of their needs by showing how to solve most problems arising from their daily exercise practice.

### 3.1. Complication screening

Actually the present section deals specifically with insulin-deficient patients, i.e. those who rely only on exogenous administration to keep metabolically stable. The vast majority of such patients is represented by children, adolescents and young-adult people with T1DM who have been practicing sports and are still willing to do that: they need especially to be educated on how to exercise safely and effectively and therefore selection criteria for T1DM patients to be addressed to an exercise program are different from those for T2DM, of course, most of who are at higher CVR.

### 3.2. Selection

In our view best criteria to address T1DM patients to exercise are:

- o age $\leq$30 years and disease duration <10 years
- o age >30 years but no chronic diabetic complications
- o being on a basal/bolus regimen or pump
- o any others with $\leq$15% risk for fatal cardiovascular events within 10 years according to validated risk engines

T1DM children are mostly characterized by normal or low BMI and, due to their typical exogenous insulin related glucose oscillations, are expected to decrease HbA1c by only 0.3% [29] despite benefiting from exercise in any case as shown by low total daily insulin requirement, low risk for both severe hypoglycemic or ketoacidosis episodes and low rates of micro- and macro-complications [30,31].

Before discussing the topic in depth, we suggest to keep in mind a basic concept: intensive resistance exercise followed by longer lasting endurance sessions represents a very good metabolic strategy for people with T1DM. This depends on the fact that hypoglycemic risk gets virtually null when the inevitably high glucose levels attained as a consequence of the sudden release of anti-insulin hormones (mainly adrenalin, glucagon and cortisol) during explosive power workouts are let steadily decrease with aerobic exercise until reaching the normal range.

Patients learn how to adapt CHO amount and timing, as well as, insulin doses to energy expenditure and exercise intensity to their own individual balance, which is generally known as the “trial and error” method. Still a more rational systematizing approach to the matter warrants the attempt we are making and hopefully might turn out to be successful in the end.

### 3.3. Motivation, education

The responsibility assignment matrix is almost the same as the one already described for T2DM except for steps 3, 5, 6 and 9 (see Table 5). In fact most T1DM patients are highly motivated to exercise themselves because of their younger age with frequently occurring spontaneous participation in sports events. Opposite to the others, however, they (i) deserve more numerous and longer-lasting education sessions going deeper into exercise and insulin action details, (ii) need expert personalized therapeutic indications to be (iii) consistently adapted to progressive training-related insulin and CHO requirement changes through technology updates and a frequently occurring verification steps.

A crucial aspect is education, instead, because good long term results are expected only when patients bound to rely only on exogenous insulin for their metabolic balance are fully aware of diabetes pathophysiology and of updated technical details on best treatment strategic options.

**Table 5**
T1DM ERCP responsibility assignment matrix.

| NEEDS | RESPONSIBLE PERSONS | ACTIONS |
|---|---|---|
| 1. Complication screening | Diabetes specialist | 1 doctor appointment |
| 2. Selection | Diabetes specialist | Virtually no need |
| **3. Motivation** | | |
| o assessment | Nurse | Virtually no need |
| | Diabetes specialist | Virtually no need |
| o counseling | Adapted Exercise Specialist (AES) | 1 AES appointment |
| **4. Evaluation** | | |
| o anthropometry | Nurse | 1 nurse appointment |
| o metabolic | Diabetes specialist | 1 doctor appointment |
| o performance | AES | 1 AES appointment |
| 5. Education | Diabetes Team/Educator | 2-4 structured sessions |
| 6. Personalized therapeutic indications | Diabetes specialist | 1-2 doctor appointments |
| 7. Planning | AES | 1 AES appointment |
| 8. Realization | Regularly spaced supervised sessions | 5 AES appointments |
| **9. Verification** | | |
| o anthropometry | Nurse | 1 nurse appointment |
| o clinical/metabolic | Diabetes specialist | 1-2 doctor appointments |
| o performance | AES | 1 AES appointment |

### 3.4. Education

#### 3.4.1. Structured education plan

This is absolutely warranted to empower patients by making them fully aware of pathophysiologic mechanisms involved in their disease *per se* and in treatment strategies. Such approach enables people to make conscious decisions during their daily life by understanding exactly how to change food intake and treatment details (e.g. dose and timing) relative to a specific exercise session.

People should be aware that under normal conditions exercise blunts insulin production and progressively increases circulating levels of the so called "stress hormones", including catecholamines (i.e. adrenalin and norepinephrine) and glucagon initially and cortisol after about 1 h. All the latter are also know as "anti-insulin" hormones due to their inner hyperglycemic properties due to increased gluconeogenic and glycogenolytic effects in both liver and muscles with accompanying increased free fatty acid entering the blood stream. At the same time insulin receptors on muscle cell membranes get more sensitive, thus increasing glucose uptake and utilization for energy supply. Insulin deficient patients should also understand that so subtle a mechanism is deranged in their body as they rely only on exogenous insulin and therefore have to know exactly expected blood insulin levels at a specific time after injection. During the first 2–3 h after meal-time boluses, relative insulin excess hinders liver and muscle glycogenolysis, thus causing glucose to decrease dramatically; the opposite occurs 4–5 h after bolus injection, especially when the "tail" of previous long-acting analogs and receptor competition by massively released free fatty acids deprive the subject of most insulin effects (Fig. 2).

#### 3.4.2. Education topics

*3.4.2.1. Effects of different exercise types per se on glucose metabolism.* **Endurance (aerobic) exercise** (walking, jogging, running, cycling, swimming or similar activities): it lasts over 1 h and entails a huge energy expenditure (even thousands calories) thanks to full oxygen utilization from free fatty acids and both muscle/liver

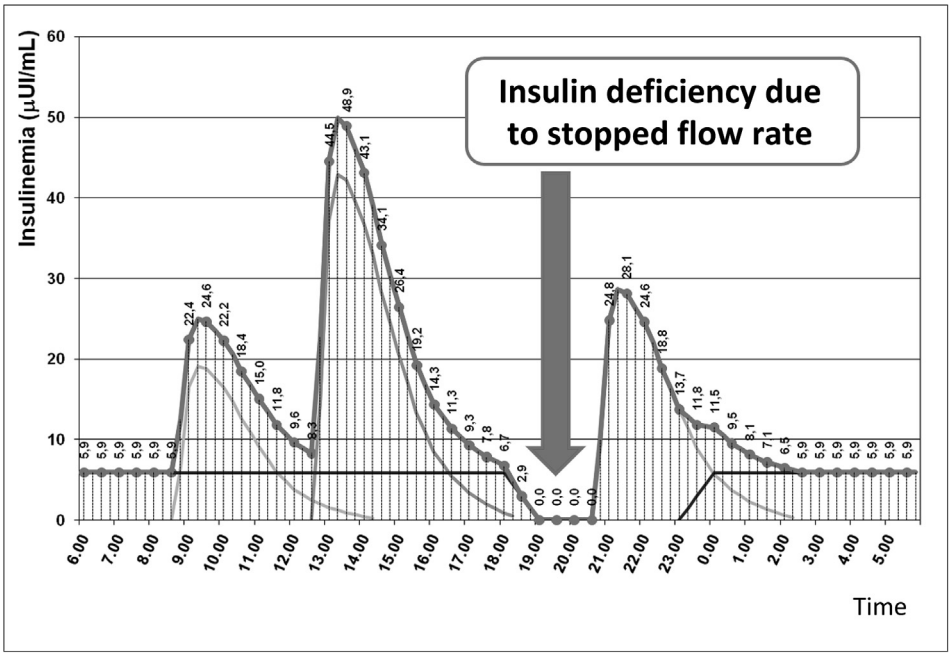



**Fig. 2.** Changes in insulin profile in T1DM patients as referred to the treatment schedule (adapted from Francescato et al., 2015) [32].

stored and circulating glucose, thus causing blood glucose to decrease according to a steady and predictable trend.

**Resistance (anaerobic) exercise** (power training, short duration high intensity exercise bouts, etc.): it trains people for strength and utilizes substrates even under poor oxygen conditions and may be:

- **lactic acid free** (jumps, launches, weight lifting, 100 m dashes, etc.): these are characterized by very short duration, low energy expenditure and utilization of readily available ATP and phosphocreatine energy stores. They are really challenging for the cardiovascular system yet almost metabolically neutral except for possible glucose spikes due to competition-related mental stress and/or strenuous effort.
- **lactic acid associated** (400–800 m runs, hurdle, anaerobic phases of team sports matches, etc.): these are characterized by short (1–5 min) and incomplete combustion of readily available or glycogenolysis-dependent glucose. They are rather challenging for the cardiovascular system and cause stress-related post-exercise hyperglycemia, often followed by late onset hypoglycemic events due to compensatory non-insulin mediated glycogen resynthesis [33].

This is why people should be informed that to feel well and maintain high performance levels it might better to start aerobic exercise with slightly elevated glucose levels (i.e 120–180 mg/dL), which will in fact get lower regularly over time, while in case of anaerobic exercise it would be the case to start with normal levels (90–120 mgdL), which in fact will tend to increase during the session.

As referred to glucose levels as recorded both before and during exercise, Table 6 might be of great help to let people understand why their feelings change so much from session to session and thus convince them of the need to look for best strategies to keep as much as possible within the range associated with best performance levels.

*3.4.2.2. Glucose utilization as referred to exercise intensity/duration and training.* At low intensity fatty acids are prevalently utilized, thus keeping hypoglycemic risk low, and only when the effort increases glucose comes into play [34].

Therefore, by using sophisticated software or most often just experience, regularly exercising people with T1DM always try to calculate in advance how much glucose levels will decrease during exercise and the amount of CHO expected to be needed to restore muscle and liver glycogen reserve, thus preventing late onset hypoglycemia.

T1DM people should also be aware that, with both training [35] and exercise duration exceeding 2 h, substrate utilization shifts from glucose to FFA, thus contributing to prevent hypoglycemia.

In any case, the most effective solution against hypoglycemia is to monitor blood glucose frequently enough, i.e. at least half an hour and immediately before start, half an hour after start and hourly thereafter in case of long lasting sessions.

### 3.5. Personalized therapeutic indications

*3.5.1. How to personalize treatment in T1DM.* Due to all the above patients should be made aware that 80% glucose utilized during the first 30 min of exercise comes from muscle glycogen and such mechanism would be blunted by any insulin excess. This entails the need to learn how much they should increase CHO intake especially in case of sessions starting soon after meal–related insulin boluses and how to attain insulin levels decreased enough to prevent hypoglycemia while taking into account effort intensity as well. This may be realized by reducing meal-time both CHO content and bolus doses by at least 50%, which should be followed by a still 50% lower insulin bolus but an increased CHO intake at the subsequent meal. With reference to that it is possible to determine CHO grams needed for the following 2 to 3 meals to resynthesize originally available glycogen stores by dividing expected caloric expenditure by 4 (i.e the energetic yield of 1 g CHO). People treated by long acting analog injections might find it rather difficult to get lower baseline insulin levels efficiently enough by a smart exercise timing plan but they should better ingest 15–30 g CHO at 30 min intervals in that case for up to 1 h. Insulin pump users get better results, instead, by reducing their flow rate by 25% some 45–60 min before a low intensity exercise, by 75% before a high intensity exercise and by only 50% for intermediate intensities (see Table 7). In any case at least 15 g CHO should be ingested before exercise to compensate for expected glycogenolysis inhibition due to the increased insulin levels expected to occur just at the beginning of each session, as depicted in Fig. 3 [36].

*3.5.2. Technology innovation.* What really makes the difference nowadays is progress in technology: subcutaneous continuous glucose monitoring (CGM) allows T1DM people to observe changes over time as has never been possible before and to correct any insulin defects or excess even in advance of their expected consequences thanks to the so called “trend arrows”. In greater detail, most available subcutaneous sensors display glucose values every fifth minute and generate a smooth user-friendly curve on the device screen along with the change rate and direction of the last glucose level recording. Being less invasive and easily interfaced with most common smart-phones, CGM devised are quite well accepted by patients and have even been shown to enhance metabolic control *per se* by simplifying insulin/CHO adaptation strategies [37] as depicted in Table 7 [38] and Fig. 4.

The flow chart presented in Table 8 provides a schematic representation of the decision making algorithm we use to help

**Table 7**
Bolus adaptations to PA intensity/duration (adapted from Rabasa-Lhoret et al., 2001) [38].

| INTENSITY | DURATION | |
|---|---|---|
| | 30 min | 60 min |
| light (≈25% VO2max) | reduce bolus by 25% | reduce bolus by 50% |
| moderate (≈50% VO2max) | reduce bolus by 50% | reduce bolus by 75% |
| high (≈75% VO2max) | reduce bolus by 75% | disregard bolus |

**Table 6**
Glucose levels with respect to metabolic effects, feelings and performance.

| Glucose (mg/dL) | Metabolic effect | Feeling | Performance |
|---|---|---|---|
| <100 | glucose can't supply enough energy to muscle and brain | weakness | poor |
| 100–180 | adequate energy supply | well being | optimal |
| 180–250 | glucose has difficulty in getting into the cells | variable | impaired |
| >250 | glucose has great difficulty in getting into the cells | extreme fatigue | poor |
| >250 + ketosis | as above + progressively increasing glucose levels | extreme fatigue, headache, muscle cramps | completely compromised |

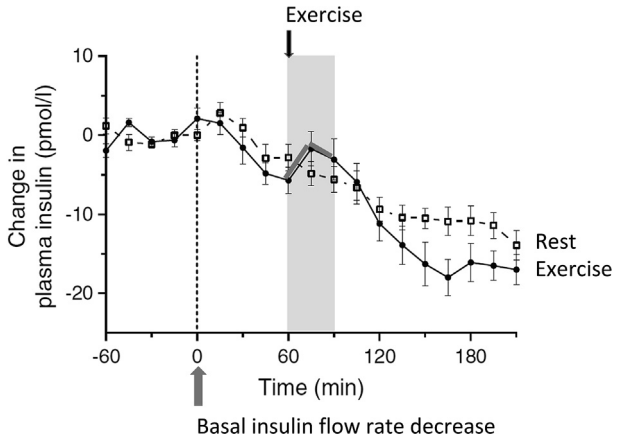



**Fig. 3.** Increased insulin levels occurring immediately after starting exercise (adapted from McAuley et al., 2016) [36].

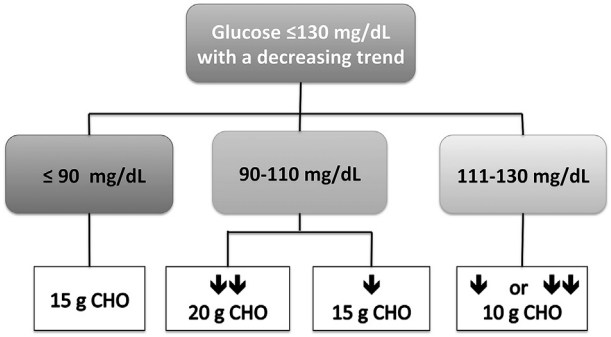



**Fig. 4.** Schematic representation of suggested fast-absorbed CHO intake as referred to glucose determinations combined with trend arrows (adapted from Riddle et al., 2011 [39].

people on either multiple insulin injection regimens or pumps adapt CHO intake and insulin dose adaptation to different conditions [33].

*3.5.3. Planning, realization and verification.* These phases are quite similar to those described for T2DM but most of them depend on the effectiveness of previous education sessions [40.41], as well as, on careful exercise planning activities by the whole diabetes care team including the AES (see Table 3).

Realization phase works better when both patient and care team fill in a shared planning matrix (an example of which is provided by Table 9) and all matrices will be collected to be verified and analyzed at the end of a defined period.

## 4. Conclusions

The strong need for qualitative and appropriate interventions warrants clinical pathways to be issued in support of assistance: our paper tries to take the first step towards the definition of shared protocols meant at providing DM patients with the best possible exercise prescription and support activities within a certain setting.

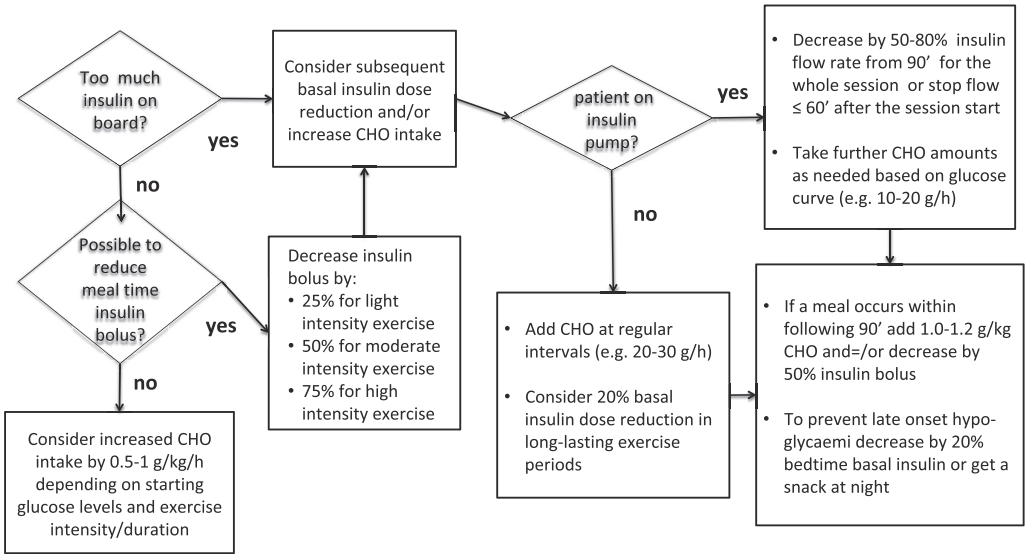
"Trials and errors" might still be a suitable method [2], of course, but structured care pathways have become a strong demand for all people with DM. This paper tried to cope with this problem by starting to fill a gap between theory a practice by joining evidences from the literature with personal experience from DM patients and some of their diabetes specialists living close to them on sports fields as we are.

Ours represents only a first step, of course, but we hope our paper will pave the way to many other publications in the field for the sake of better quality of life and lower cardiovascular risk in an ever increasing number of people with DM.

**Table 9**
Planning and verification matrix.

| DATE … … … … … … … ….. | | |
|---|---|---|
| Item description | What do i expect? | What will i do? |
| Exercise type | | |
| Insulin on board | | |
| Intensity | | |
| Starting blood glucose | | |
| Training level | | |
| Duration | | |

**Table 8**
Exercise related decision making algorithm in T1DM (adapted from Riddell et al., 2017) [33].



## Conflicts of interest

The author declare they have no conflicts of interest to disclose.

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## Authorship

All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.

## References

[1] http://aemmedi.it/standard-di-cura. [Accessed 9 June 2018].
[2] Colberg SR, Sigal RJ, Yardley JE, et al. Physical activity/exercise and diabetes: a position statement of the American diabetes association. Diabetes Care 2016;39:2065–79.
[3] Morrato EH, Hill JO, Wyatt HR, et al. Physical activity in US adults with diabetes and at risk for developing diabetes. Diabetes Care 2007;30:203–9.
[4] Cooper AJ, Brage S, Ekelund U, et al. Association between objectively assessed sedentary time and physical activity with metabolic risk factors among people with recently diagnosed type 2 diabetes. Diabetologia 2014;57:73–82.
[5] Colak TK, Acar G, Dereli EE, et al. Association between the physical activity level and the quality of life of patients with type 2 diabetes mellitus. J Phys Ther Sci 2016;28:142–7.
[6] Casals-Vazquez C, Suárez-Cadenas E, Estébanez Carvajal FM, et al. Relationship between quality of life, physical activity, nutrition, glycemic control and sarcopenia in older adults with type 2 diabetes mellitus. Nutr Hosp 2017;34:1198–204.
[7] Awotidebe TO, Adedoyin RA, Oke KI, et al. Relationship between functional capacity and health-related quality of lyfe of patients with type-2 diabetes. Diabetes Metab Syndr 2017;11:1–5.
[8] Madden KM. Evidence for the benefit of exercise therapy in patients with type 2 diabetes. Diabetes Metab Syndr Obes 2013;6:233–9.
[9] Zanuso S, Balducci S, Jimenez A. Physical Activity, a key factor to quality of life in type 2 diabetic patients. Diabetes Metab Res Rev 2009;25(Suppl 1):S24–8.
[10] Balducci S, Zanuso S, Nicolucci A, et al. For the Italian Diabetes Exercise Study (IDES) Investigators. Effect of an intensive exercise intervention strategy on modifiable cardiovascular risk factors in subjects with type 2 diabetes mellitus - a randomized controlled trial: the Italian diabetes and Exercise Study (IDES). Arch Intern Med 2010;170:1794–803.
[11] Church TS, Cheng YJ, Earnest CP, et al. Exercise capacity and body composition as predictors of mortality among men with diabetes. Diabetes Care 2014;27:83–8.
[12] Chudyk A, Petrella RJ. Effects of exercise on cardiovascular risk factors in type 2 diabetes- a meta analysis. Diabetes Care 2011;34:1228–37.
[13] Sigal RJ, Kenny GP. New evidence for the value of supervised exercise training in type 2 diabetes mellitus. Arch Intern Med 2010;170:1790–1.
[14] Colberg SR, Sigal RJ, Fernhall B, et al. American College of sports medicine; American diabetes association. Exercise and type 2 diabetes: the American College of sports medicine and the American diabetes association: joint position statement executive summary. Diabetes Care 2010;33:2692–6.
[15] Reid RD, Tulloch HE, Sigal RJ, et al. Effects of aerobic exercise, resistance exercise or both, on patient-reported health status and well-being in type 2 diabetes mellitus: a randomised trial. Diabetologia 2010;53:632–40.
[16] Sigal RJ, Kenny GP, Boulé NG, et al. Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: a randomized trial. Ann Intern Med 2007;147:357–69.
[17] SénMéchal M, Johannsen NM, Swift DL, et al. Association between changes in muscle quality with exercise training and changes in cardiorespiratory fitness measures in individuals with type 2 diabetes mellitus: results from the HART-D study. PLoS One 2015;10(8):e0135057. https://doi.org/10.1371/journal.pone.0135057. Published online 2015 Aug 7.
[18] Boulé NG, Kenny GP, Haddad E, et al. Metanalysis of the effect of structured exercise training on cardiorespiratory fitness in type 2 diabetes mellitus. Diabetologia 2003;46:1071–81.
[19] Joseph A-M, Adhihetty PJ, Leeuwenburgh C. Beneficial effects of exercise on age-related mitochondrial dysfunction and oxidative stress in skeletal muscle. J Physiol 2016;594:5105–23.
[20] Umpierre D, Ribeiro PA, Schaan BD, Ribeiro JP. Volume of supervised exercise training impacts glycaemic control in patients with type 2 diabetes: a systematic review with meta-regression analysis. Diabetologia 2013;56:242–51.
[21] http://www.cuore.iss.it/valutazione/carte.asp. [Accessed 10 June 2018].
[22] PACE Research and Development Team. Patient-centered assessment and counseling for exercise and nutrition. San Diego State University Foundation and San Diego Center for Health Interventions; 1999.
[23] Prochanska JO, Di Clemente CC. Transtheoretical Therapy: toward a more integrative model of change. Am J Health Promot 1982;12:11–2.
[24] Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. Am J Health Promot 1997;12:38–48.
[25] Calfas KJ, Sallis JF, Zabinski MF, et al. Preliminary evaluation of a multicomponent program for nutrition and physical activity change in primary care: PACE+ for adults. Prev Med 2002;34:153–61.
[26] PACE Canada. Health provider's guide to counseling for healthy active living. Ottawa: Canadian Fitness and Lifestyle Research Institute; 2000.
[27] Colberg SR, Castorino K, Jovanovič L. Prescribing physical activity to prevent and manage gestational diabetes. World J Diabetes 2013;4:256–62.
[28] Thosar SS, Bielko SL, Mather KJ, Johnston JD, Wallace JP. Effect of prolonged sitting and breaks in sitting time on endothelial function. Med Sci Sport Exerc 2015;47:843–9.
[29] Corigliano G, Iazzetta N, Corigliano M, Strollo F. Blood glucose changes in diabetic children and adolescents engaged in most common sports activities. Acta Biomed 2006;77(Suppl 1):26–33.
[30] Jerums G, MacIsaac RJ. Diabetic nephropathy: how does exercise affect kidney disease in T1DM? Nat Rev Endocrinol 2015;11:324–5.
[31] Salem MA. Is exercise a therapeutic tool for improvement of cardiovascular risk factors in adolescents with type 1 diabetes mellitus? A randomised controlled trial. Diabetol Metab Syndrome 2010;2:47.
[32] Francescato MP, Stel G, Stenner E, Geat M. Prolonged exercise in type 1 diabetes: performance of a customizable algorithm to estimate the carbohydrate supplements to minimize glycemic imbalances. PLoS One 2015 Apr 28;10(4):e0125220. https://doi.org/10.1371/journal.pone.0125220. eCollection 2015.
[33] Riddell MC, Gallen IW, Smart CE, et al. Exercise management in type 1 diabetes: a consensus statement. Lancet Diabetes Endocrinol 2017;5:377–90.
[34] Brooks GA, Mercier J. Balance of carbohydrate and lipid utilization during exercise: the "crossover" concept. J Appl Physiol 1985;76:2253–61. 1994.
[35] Friedlander AL, Casazza GA, Horning MA, Huie MJ, Brooks GA. Training-induced alterations of glucose flux in men. J Appl Physiol 1985;82:1360–9. 1997.
[36] McAuley SA, Horsburgh JC, Ward GM, et al. Insulin pump basal adjustment for exercise in type 1 diabetes: a randomised crossover study. Diabetologia 2016;59:1636–44.
[37] Vuattolo O, Francescato MP, Della Mea V, Accardo A. A smartphone application for preventing exercise-induced glycemic imbalances in type 1 diabetic patients. Stud Health Technol Inform 2012;180:1035–9.
[38] Rabasa-Lhoret R, Bourque J, Ducros F, Chiasson JL. Guidelines for premeal insulin dose reduction for postprandial exercise of different intensities and durations in type 1 diabetic subjects treated intensively with a basal-bolus insulin regimen (ultralente-lispro). Diabetes Care 2001;24:625–30.
[39] Riddell MC, Milliken J. Preventing exercise-induced hypoglycemia in type 1 diabetes using real-time continuous glucose monitoring and a new carbohydrate intake algorithm: an observational field study. Diabetes Technol Ther 2011;13:819–25.
[40] Geat M, Stel G, Poser S, Driussi C, Stenner E, Francescato MP. Whole-body glucose oxidation rate during prolonged exercise in type 1 diabetic patients under usual life conditions. Metabolism 2013;62:836–44.
[41] Buoite Stella A, Assaloni R, Tonutti L, Manca E, Tortul C, Candido R, Francescato MP. Strategies used by patients with type 1 diabetes to avoid hypoglycemia in a 24×1-hour marathon: comparison with the amounts of carbohydrates estimated by a customizable algorithm. Can J Diabetes 2017;41:184–9.