Algorithms compared and characteristics of commercial systems

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Closed-loop systems available in Italy

Which system for which patient?

Why this topic matters

As more systems become available, choosing a system becomes a clinical decision, not a simple procurement step.

The best system is the one the person can use safely, correctly, and consistently.

Start from the **person**, not from the device.

Then match three layers: **pump characteristics**, **CGM characteristics**, and **whole-system behavior**.

Shared decision-making is essential because daily usability often determines long-term outcomes more than technical specifications alone.

What all HCL systems have in common

A CGM measures interstitial glucose and glucose trends.

A pump delivers rapid-acting insulin subcutaneously.

An algorithm adjusts insulin delivery using sensor data and insulin-on-board information.

Meal boluses and some user input remain necessary; this is why the systems are “hybrid”.

Glucose and insulin data can be shared with clinics and, in many cases, caregivers.

Control algorithms

Proportional–Integral–Derivative model

This mathematical model calculates the insulin delivery rate based on what has occurred over the preceding minutes, determining the insulin dose according to:
- the difference between the glycemic target and the measured glucose level (proportional component);
- the difference between the areas under the curves described by the target glucose level and the measured glucose level, taking into account the insulin delivered (integral component);
- the rate and direction of change in the measured glucose levels (derivative component).
It is a **reactive** system, as it responds to glycemic variations without making predictions.

Model Predictive Control

This mathematical model is able to predict glucose levels in the near future and calculate the insulin infusion rate by minimizing the difference between the glucose concentration predicted by the model and the target glucose trajectory within a given time horizon.
It is a **proactive** system, as it anticipates the effect of insulin.

Fuzzy Logic model

Model that calculates the insulin dose based on measured glucose levels and on the direction and rate of change of glucose values, mimicking the logic followed by diabetologists.

Where the algorithm lives

- Smartphone app
- Pump
- Pod
- Dedicated handheld controller

Clinical relevance: privacy, battery life, work restrictions, risk of losing devices, and preference for or against phone-based control.

Pump choice: tethered or patch

• Tethered pumps deliver insulin from a reservoir through tubing and a subcutaneous infusion set.
• Patch pumps integrate the reservoir and cannula into a device attached directly to the skin.

Patch advantages: discretion, less interference with movement, fewer tubing-related frustrations, and easier acceptance for some youths and women.
Tethered advantages: reservoir flexibility, infusion-set options, and in some cases longer wear options.

Pump details that change everyday life

- Size and weight affect comfort, discretion, exercise, and visibility under clothing.
- Reservoir capacity should match total daily insulin dose and desired refill frequency.
- Prefilled cartridges may help people with visual limitations, dexterity problems, or caregiver burden.
- Infusion-set duration matters for skin irritation, inflammation, site failure, and routine disruption.
- Battery type and water resistance can be decisive for travel, swimming, outdoor activity, and daily convenience.

CGM choice can decide the system

- Some HCL systems integrate with several CGM devices.
- Non-adjunctive CGM use reduces the need for confirmatory capillary glucose checks before treatment decisions.
- Integrated CGM status gives additional reassurance for closed-loop performance.
- Approved sensor sites matter for aesthetics, lipodystrophy, occupational needs, and accuracy.
- Sensor size, duration, and insertion simplicity influence acceptance and long-term continuity.

Glucose targets: the most clinical part of the algorithm

Treat-to-range or treat-to-target
Which target range
Fix or modifiable target
Single or multiple glucose targets across time blocks.

Target flexibility is useful in pregnancy, fear of hypoglycemia, unstable complications, shift work, and glucocorticoid therapy.

How much can the clinician and user adjust?

- Minimal adjustment can be desirable for people who prefer simplicity and less fine-tuning.
- More adjustable settings can help highly engaged users and complex clinical patterns.
- Common parameters include glucose target, insulin-to-carbohydrate ratio, insulin sensitivity factor, active insulin time, basal profile, total daily dose, and body weight.

Meal management: when algorithms meet real life

Accurate carbohydrate counting remains useful, but HCL systems can partially compensate for approximate entries.

- Add Meal/snack and strategies for slowly absorbed meals.
- Extended bolus, with longer extension
- High-fat meal feature with biphasic bolus logic and prolonged adjustment.
- Custom foods for frequently consumed meals and snacks.
- Auto Meal for meal activity announcements.

Physical activity and hypoglycemia prevention

All systems provide a way to relax targets or reduce insulin delivery around activity.

- Ease-off raises the target and reduces insulin delivery.
- Exercise Activity and alternative personal profiles can be combined.
- Physical Activity, Zen mode, and rescue-carbohydrate recommendations.
- Temporary target or activity features.
- Physical Activity reduces insulin delivery during exercise.

Challenging days: illness, stress, hormones

Intercurrent illness, glucocorticoids, stress, puberty, and menstrual cycles can substantially raise insulin needs.

- Boost function that increases algorithm responsiveness.
- Personal profiles can represent different days or routines.

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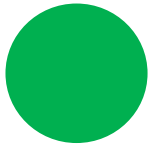
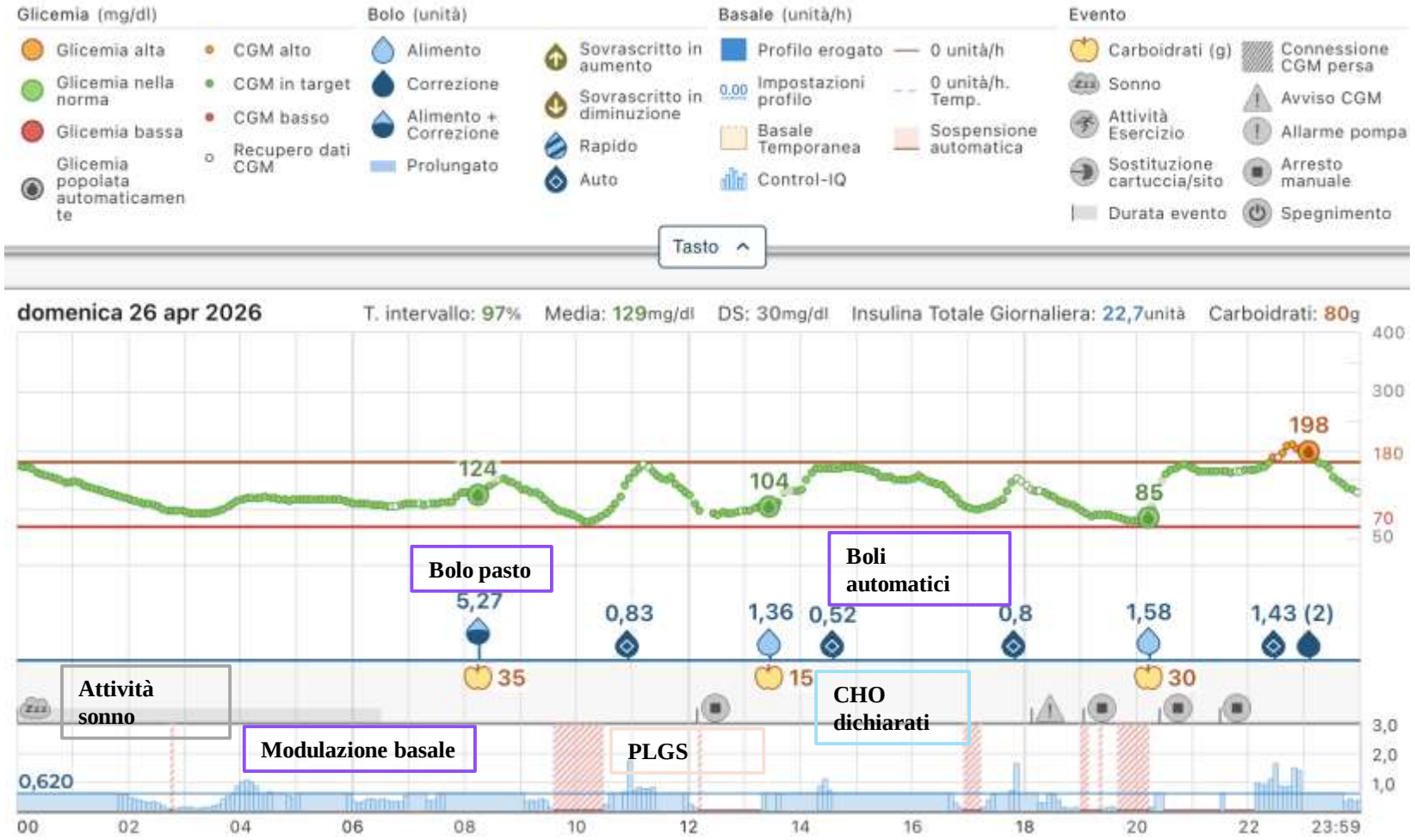
Matching system to lifestyle and preferences

- Active lifestyle or sport: patch pump design, water resistance, activity modes, and sensor/pump site options matter.
- Privacy and body image: device size, pump visibility, phone-based bolusing, and tubing preferences matter.
- Work restrictions: smartphone dependence may be an advantage or a barrier.
- Frequent travel or busy routines: battery type, upload method, reservoir size, sensor duration, and help-line structure matter.
- Caregiver involvement: the depth and modality of data sharing can affect safety and psychosocial burden.



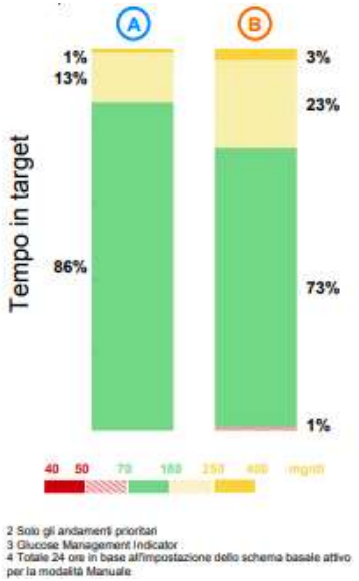
• Approved use: type 1 diabetes **≥6 years** in EU and FDA.
• Insulin requirement: **10–100 U/day**; **body weight 25–140 kg**.
• Compatible insulins: lispro, aspart, faster aspart, ultra-rapid lispro
• Pump: **size 79 × 51 × 15 mm; weight 125 g.**
• Reservoir: 300 U.
• Water resistance: **1 m for 30 min**.
• CGM compatibility: **G6** and **G7**
• Sensor duration and size: G6, **10 days** and 46 × 30 × 15 mm; G7, **10.5 days** and 24 × 27 × 5 mm.
• Algorithm: **Control-IQ; model-predictive control located on the pump.**
• Automated insulin delivery: **algorithm-driven basal insulin delivery and correction boluses.**
• Extended boluses: yes, limited to 2 h
• GT behavior: **predefined target range**, 112.5–160 mg/dL.
• Modifiable settings: **basal insulin rates, ICR*, ISF, TDD, body weight**.
• Meal tool: **extended bolus** for prolonged absorption patterns.
• Physical activity: **Exercise Activity uses target range 140–160 mg/dL and basal suspensions for predicted glucose <80 mg/dL.**
• Personal profiles: **up to six profiles** with softer basal doses, ICR, and ISF.
• Other functions: **Sleep Activity** targets 112.5–120 mg/dL without autocorrections
• Data upload: **via app or PC**; remote bolusing: **yes.**
• Distinctive features: extended bolus, Exercise Activity, Sleep Activity, remote bolusing, and up to six personal profiles.
• **Potential fit: people with variable routines, different work/rest days, complex profiles, and high reservoir needs.**


Riepilogo CGM
Media 150 mg/dl
Time in Range 78 %
Tempo di utilizzo CGM 100 %
Deviazione standard 47 mg/dl
Coefficiente di variazione 31 %
GMI 6,9 %
Confronto tempo negli intervalli
Attuale 2 settimane
Precedente 2 settimane
> 250
181 - 250
Nell'intervallo 70 - 180
54 - 69
< 54
3,2%
19%
78%
0,3%
0%
2,3%
21%
76%
0,3%
0%
Riepilogo Control-IQ
Tempo di attività 91 % 12 gg 14 h
Control-IQ DISATTIVO 0 % 0 h 0 min
CGM non attivo 0 % 0 h 26 min
Pompa inattiva 8 % 1 g 4 h
Media Att. sonno
Media Att. esercizio
Durata 6 h
Settimanale 7 volte
Durata 0 h
Settimanale 0 volte


Glicemia (mg/dl)
Glicemia alta
Glicemia nella norma
Glicemia bassa
Glicemia popolata automaticamente
CGM alto
CGM in target
CGM basso
Recupero dati CGM
Bolo (unità)
Alimento
Correzione
Alimento + Correzione
Prolungato
Sovrascritto in aumento
Sovrascritto in diminuzione
Rapido
Auto
Basale (unità/h)
Profilo erogato
0 unità/h
Impostazioni profilo
0 unità/h. Temp.
Basale Temporanea
Sospensione automatica
Control-IQ
Evento
Carboidrati (g)
Sonno
Attività Esercizio
Sostituzione cartuccia/sito
Durata evento
Connessione CGM persa
Avviso CGM
Allarme pompa
Arresto manuale
Spegnimento
Tasto
domenica 26 apr 2026
T. intervallo: 97%
Media: 129mg/dl
DS: 30mg/dl
Insulina Totale Giornaliera: 22,7unità
Carboidrati: 80g
400
300
180
70
50
198
124
104
85
Bolo pasto
Boli automatici
5,27
0,83
1,36
0,52
0,8
1,58
1,43 (2)
35
15
30
Attività sonno
CHO dichiarati
Modulazione basale
PLGS
0,620
3,0
2,0
1,0
00
02
04
06
08
10
12
14
16
18
20
22
23:59

• Approved use: type 1 diabetes **≥2 years** in the EU; type 2 diabetes ≥18 years in the EU; **pregnancy in the EU**.
• Insulin requirement: **6–250 U/day** in the EU
• Compatible insulins: lispro, aspart, faster aspart in the EU, ultra-rapid lispro in the EU.
• Pump: **size 96 × 52 × 25 mm; weight 113 g.**
• Reservoir: 180 U or 300 U.
• Water resistance: **3.6 m for 24 h**.
• CGM compatibility: **GL 4, S Sync**.
• Sensor duration: **7 days**.
• Sensor size: **GL4**, 36 × 29 × 10 mm; **S Sync**, 28 × 28 × 5 mm.
• Algorithm: **SmartGuard**.
• Algorithm type: **proportional-integral-derivative control with insulin feedback, fuzzy logic, and predictive safety features; located on the pump.**
• Automated insulin delivery: **algorithm-driven basal insulin delivery and optional correction boluses**.
• Extended boluses: not available.
• GT options: **100, 110, or 120 mg/dL**.
• Modifiable settings: **GT, ICR*, AIT, autocorrections ON/OFF**.
• Meal tool: **Custom food list for foods, meals, or snacks to streamline bolus calculations**.
• Physical activity: **temporary GT 150 mg/dL, without autocorrections**.
• Data upload: **via app or PC**.
• Remote bolusing: no.

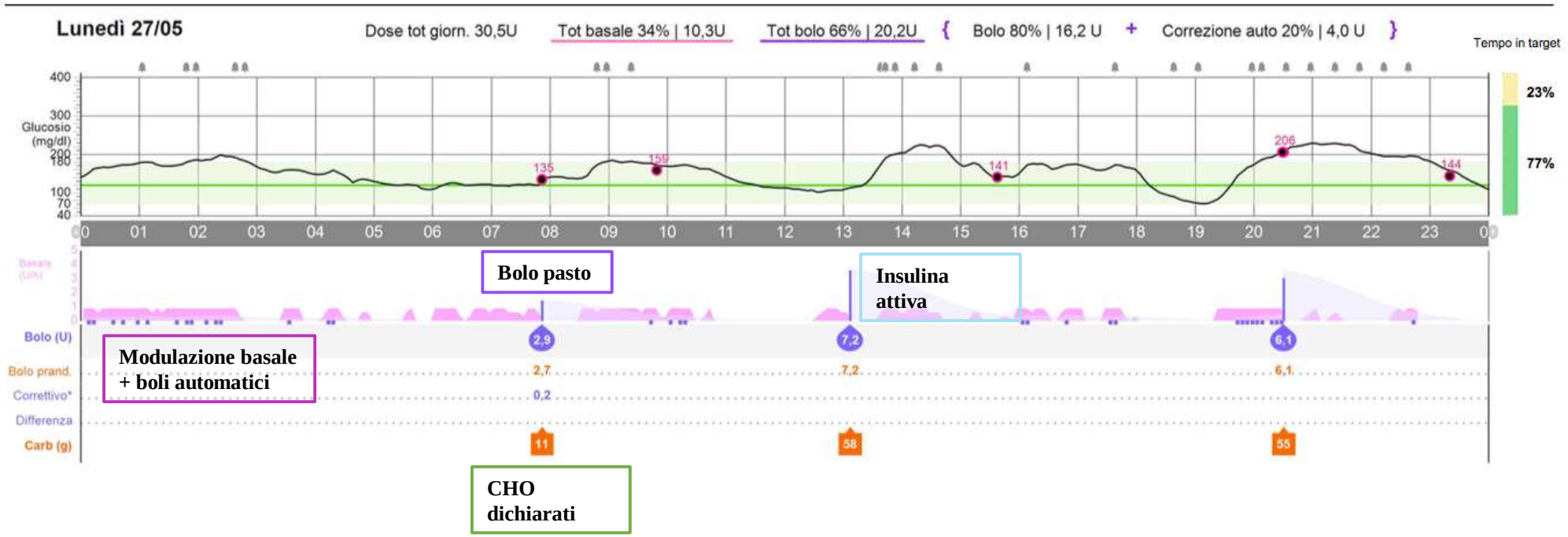
Potential fit: people preferring lower tuning burden, high insulin needs, preschool children, and pregnancy

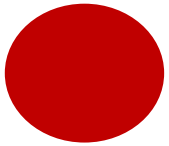


2 Solo gli andamenti prioritari
3 Glucose Management Indicator
4 Totale 24 ore in base all'impostazione dello schema basale attivo per la modalità Manuale

Uscita da SmartGuard	A	B
Nessuna calibrazione	1	1
Erogazione max SmartGuard	0	0
Erogazione min SmartGuard	0	0
Glicemia necessaria per SmartGuard	0	0
Valore sensore poco accurato	0	0
Aggiornam. sensore	0	0
Nessun valore sensore	0	0
Fine sensore	0	0
SmartGuard disattivata dall'utente	0	0
Sospensione prolungata	0	0
Periodo attesa SmartGuard	0	0
Causa non identificata	0	0

Statistiche	A	B
SmartGuard (settimana)	98% (6g 21h)	46% (3g 05h)
Modalità manuale (settimana)	1% (01h)	54% (3g 19h)
Uso sensore (settimana)	93% (6g 12h)	95% (6g 15h)
Media glucosio sensore ± DS	140 ± 40 mg/dl	149 ± 47 mg/dl
GMI[3]	6,7%	6,9%
Coefficiente di variazione (%)	28,2%	31,6%
Avvisi gluc. sens. basso/alto (al giorno)	2,9 / 11,4	7,4 / 17,0
Media glicemia	138 ± 37 mg/dl	141 ± 55 mg/dl
Glicemia / Calibrazione (al giorno)	4,9 / 3,6	6,6 / 5,3
Dose totale giornaliera (al giorno)	28,5 unità	32,4 unità
Insulina tramite bolo (al giorno)	18,7U (66%)	20,2U (62%)
Quantità correzione auto (al giorno)	2,6U (14%)	1,7U (8%)
Insul. Basale Auto/Basale (al giorno)	9,8U (34%)	12,2U (38%)
Sostituzione set / serbatoio	-- / 5,5 giorni	-- / 5,0 giorni
Carboidrati immessi / pasti (al giorno)	122 ± 10 g / 3,1	121 ± 19 g / 3,2
Tempo insulina attiva	3:00 ore	3:00 ore
Basale manuale 24 ore (% dose tot. giorn.)* (Obiettivo 50% dose tot. giorn.)	14,400U (51%)	14,400U (44%)





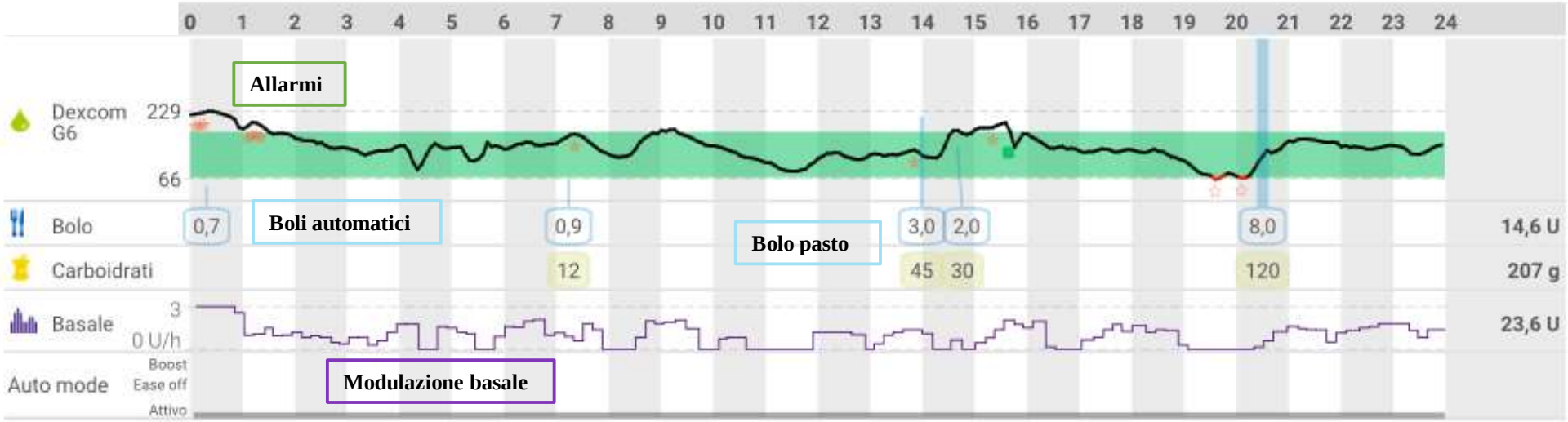
• Approved use: type 1 diabetes **≥1 year** in the EU; **pregnancy** approved in EU and FDA.
• Insulin requirement: **5–350 U/day; body weight ≥10 kg**.
• Compatible insulins: lispro, aspart, faster aspart, ultra-rapid lispro, glulisine.
• Pump: **size 78 × 46 × 16 mm; weight 83 g**.
• Reservoir: 160 U, with optional prefilled cartridge.
• Water resistance: **1 m for 60 min**.
• CGM compatibility: **G6, FL 3, FL 3 Plus**.
• Sensor duration: **10 days** with G6; **14 days** with L3; **15 days** with L3 Plus.
• Sensor size: 46 × 30 × 15 mm with G6; 19 × 19 × 3 mm with L3 and L3 Plus.
• Algorithm: **CamAPS FX; adaptive model-predictive control located on the smartphone app**.
• Automated insulin delivery: **algorithm-driven boluses every 8–12 min**.
• Extended boluses: not available.
• GT: **80–198 mg/dL, with up to 48 time blocks**.
• Modifiable settings: **GT, body weight, ICR*, ISF*, AIT*.**
• Meal tools: **Add Meal/snack adjusts insulin for extra carbohydrates based on glucose, trend, and insulin on board**.
• Slowly absorbed meal: **gradual insulin delivery over the following 3–4 h when glucose rises**.
• Physical activity: **Ease-off adaptively raises GT by up to 45 mg/dL and reduces insulin delivery**.
• Other functions: **hypoglycaemia treatment prevents insulin coverage of the rescue carbohydrate; Boost increases responsiveness by approximately 35%.**
• Data upload: **via app**; remote bolusing: **yes**.
• Distinctive features: Add Meal/snack, Ease-off, Boost, hypoglycemia treatment, and remote bolusing.
• **Potential fit: young children, pregnancy, fine target tailoring, and periods of changing insulin sensitivity**

Panoramica settimanale

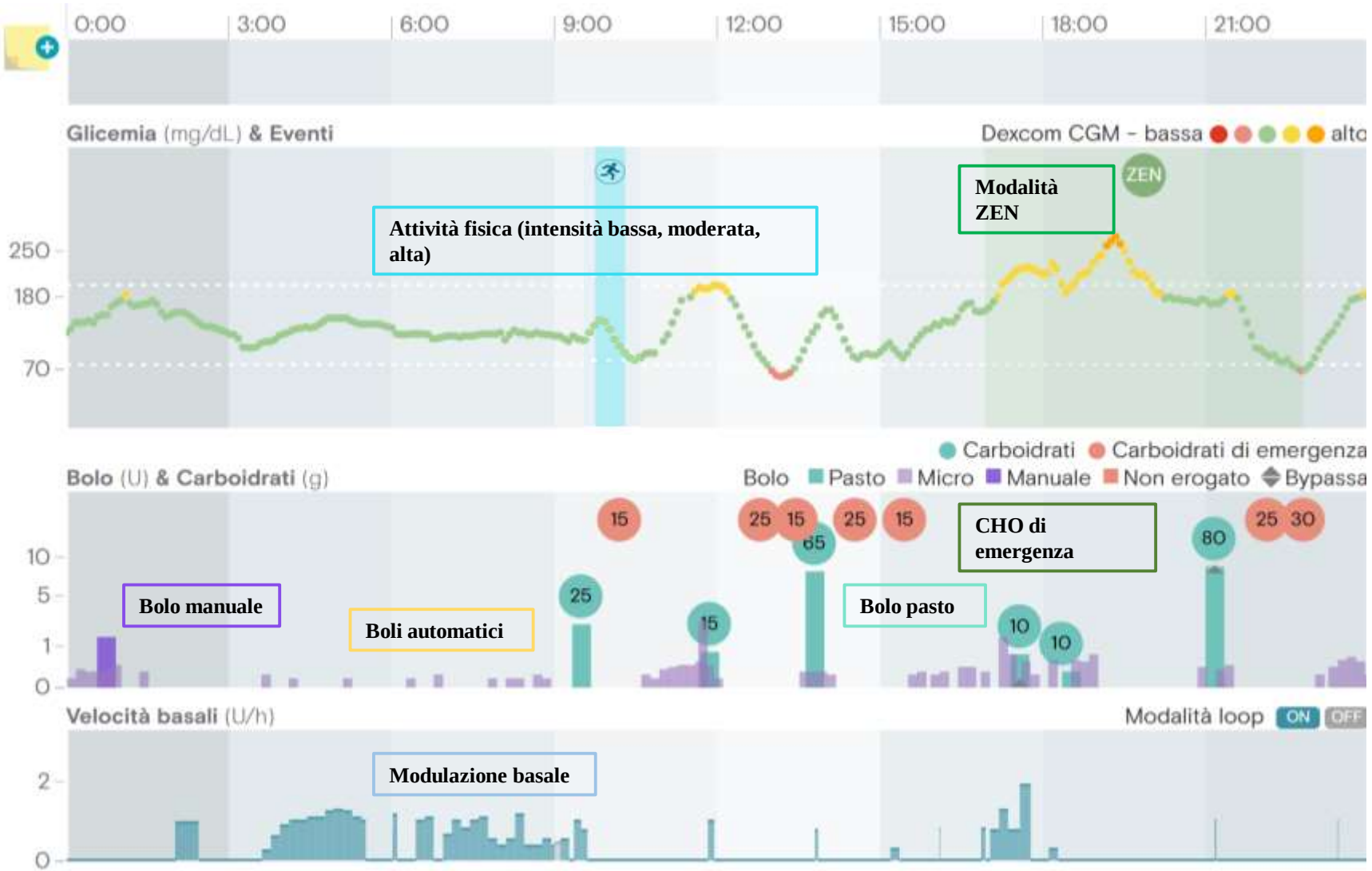
Antonietta

13% Sopra	Intervallo target [mg/dL]	70-180
86% Entro	Media del glucosio [mg/dL]	135
	Deviazione standard [mg/dL]	39
1% Sotto	Tempo al di sotto di 70 mg/dL [%]	1,4
	Tempo al di sotto di 54 mg/dL [%]	0,00

42% Bolo	Insulina totale giornaliera [U/giorno]	36,5
58% Basale	Bolo totale giornaliero [U/giorno]	15,5
	Basale totale giornaliera [U/giorno]	21,0



• Approved use: type 1 diabetes **≥18 years** in the EU.
• Insulin requirement: **8–90 U/day**.
• Compatible insulin: aspart.
• Pump: **size 84 × 52 × 10 mm; weight 122 g.**
• Reservoir: 160 U prefilled cartridge.
• Water resistance: **2.5 m for 60 min**.
• CGM compatibility: **G6**.
• Sensor duration: **10 days**.
• Sensor size: 46 × 30 × 15 mm.
• Algorithm: **DBLG1; model-predictive control located on a dedicated handheld device**.
• Automated insulin delivery: **algorithm-driven basal insulin delivery and correction boluses**.
• Extended boluses: not available.
• GT: **100–130 mg/dL**.
• Modifiable settings: **GT, hypoglycaemia threshold, hyperglycaemia aggressiveness, normoglycaemia aggressiveness, meal-specific aggressiveness for breakfast, lunch, and dinner, TDD, body weight**.
• Meal tool: **High-fat meal adjusts insulin doses for delayed hyperglycaemia with a biphasic bolus delivered at a 60-min interval**.
• Physical activity: **raises GT, hypoglycaemia threshold, and hyperglycaemia threshold by 70 mg/dL.**
• Other functions: **Rescue carbs recommend carbohydrates based on body weight and the predicted glucose-minus-GT difference**.
• Zen mode: **raises GT by 10–40 mg/dL for 1–8 h**.
• Data upload: **via handset**; remote bolusing: **yes**.
• Distinctive features: high-fat meal, Physical Activity, rescue-carbohydrate recommendations, Zen mode, and remote bolusing.
• **Potential fit: users needing additional hypoglycemia protection, structured exercise support, and complex-meal tools.**



Tempo medio giornaliero nell'intervallo

28m	2%	
2h 54m	12%	
19h 57m	83%	
31m	2%	
11m	1%	

<54 | 54-70 | 70-180 | 180-250 | >250 mg/dL

Glucosio medio (CGM) mg/dL 136

Uso dei sensori 95%

Insulina totale giornaliera media (42.9U)

Bolo	34.4 U	80%
Basale	8.5 U	20%

Tempo medio giornaliero in modalità loc

ON 96% 23h 4m | OFF 4% 56m

Carboidrati medi giornalieri	246g
Carboidrati di emergenza	48g
Insulina media giornaliera	42.9U
Peso	59 kg
Dose giornaliera ÷ Peso	0.73 U/kg
GMI (HbA1c)	6.6%

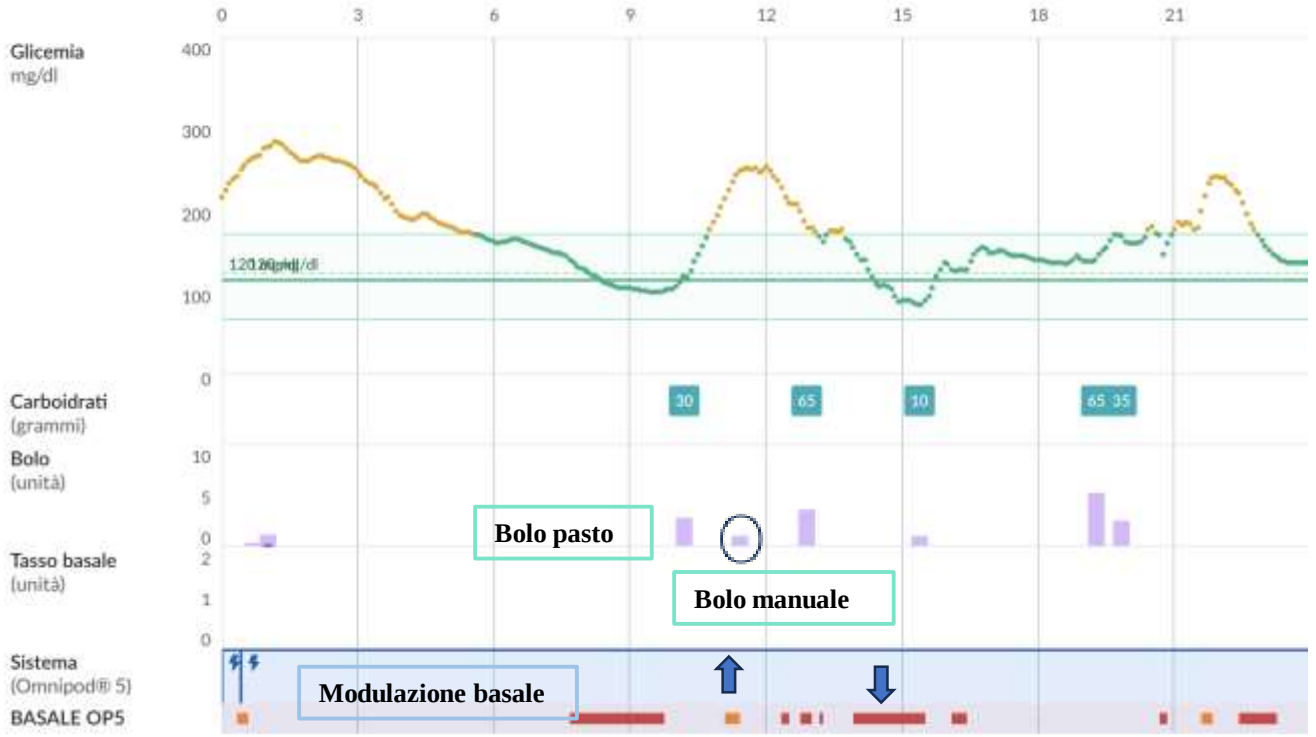
• Approved use: type 1 diabetes **≥2 years** in the EU; type 2 diabetes ≥18 years by FDA.
• Insulin requirement: **≥5 U/day**.
• Compatible insulins: lispro, aspart.
• Pump: patch pump; **size 52 × 39 × 14.5 mm; weight 26 g**.
• Reservoir: 200 U.
• Water resistance: **7.6 m for 60 min**.
• CGM compatibility: **G6, FL2 Plus, G7**.
• Sensor duration: G6, **10 days**; L2 Plus, **15 days**; G7, **10.5 days**.
• Sensor size: G6, 46 × 30 × 15 mm; L2 Plus, 35 × 35 × 5 mm; G7, 24 × 27 × 5 mm.
• Algorithm: **SmartAdjust; model-predictive control located on the Pod.**
• Automated insulin delivery: **algorithm-driven basal insulin delivery.**
• Extended boluses: not available.
• GT: **110–150 mg/dL, with up to 8 time blocks.**
• Modifiable settings: **GT, ICR*, ISF*, correct-above value*, reverse correction*, AIT***.
• Meal tool: **Custom food allows a personalized list of foods, meals, or snacks to streamline bolus calculations**.
• Physical activity: **Activity feature reduces automated insulin delivery and sets GT to 150 mg/dL.**
• Practical device feature: **tubeless patch-pump architecture with the algorithm embedded in the Pod.**
• Data upload: **via handset**.
• Remote bolusing: **yes**.
• Distinctive features: Activity feature, custom foods, remote bolusing, and discreet tubeless wear.
• **Potential fit: children, adolescents, active users, people prioritizing body freedom and avoiding tubing.**

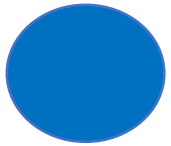
Glicemia (DISPOSITIVO CGM)

9%	**Molto alta**	> 250 mg/dl
19%	**Alta**	181-250 mg/dl
72%	**Intervallo target**	70-180 mg/dl
0%	**Bassa**	54-69 mg/dl
0%	**Molto bassa**	< 54 mg/dl

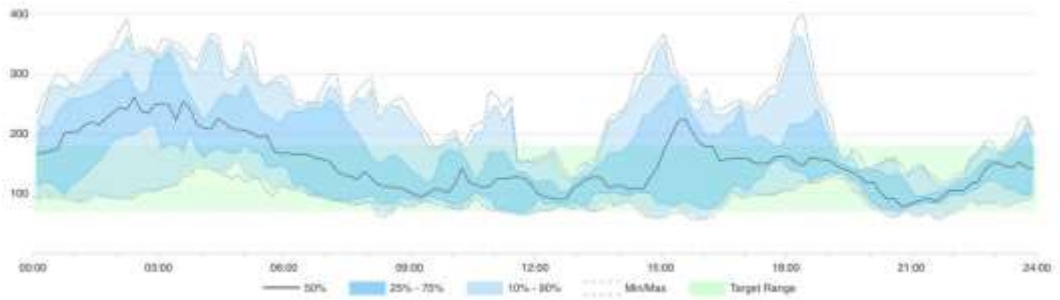
% di tempo CGM attivo	**99% (13,9 giorni)**

GMI	7.2% (55,4 mmol/mol)
Media	164 mg/dl
DS	49 mg/dl
CV	29.9%
Mediana	149 mg/dl
Più alta	314 mg/dl
Più bassa	76 mg/dl

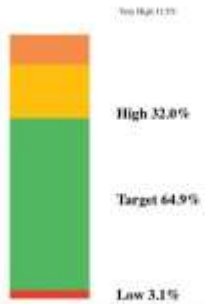




• Approved use: type 1 diabetes **≥2 years** in the EU.
• Insulin requirement: **≥10 U/day; body weight ≥22 kg**.
• Compatible insulins: lispro, aspart, glulisine.
• Pump: Patch Pump; **size 40.5 × 31.5 × 11.5 mm; weight 13.8 g**.
• Reservoir: 200 U or 300 U.
• Water resistance: **2.5 m for 60 min**.
• CGM compatibility: **Nano sensor**.
• Sensor duration: **14 days**.
• Sensor size: 28.3 × 17.8 × 5.1 mm.
• Algorithm: **APGO**.
• Algorithm type: **proportional-integral-derivative and model-predictive control; located on smartphone app or handheld device.**
• Automated insulin delivery: **algorithm-driven basal insulin delivery and optional correction boluses.**
• Extended boluses: **available with the AutoMeal function**
• GT options: **100, 110, or 120 mg/dL.**
• Modifiable settings: **GT, ICR*, ISF*, AIT*.**
• Meal tools: **Auto Meal automatically adjusts insulin delivery when a meal activity is indicated, such as breakfast, lunch, dinner, or snack.**
• Meal size: **allows small, medium, large, and extra-large carbohydrate meal announcements**.
• Physical activity: **reduces insulin delivery during exercise to help prevent hypoglycaemia**.
• Data upload: **via app or handset**; remote bolusing: **yes.**
• Distinctive features: Auto Meal, Physical Activity, remote bolusing, and very light patch-pump profile.



BG	BG/Calibration (per day)	3.9 / --
SG	AUC high > 180 mg/dL	19
	AUC low < 70 mg/dL	0
	Highest value	399 mg/dL
	Lowest value	56 mg/dL
	<54 mg/dL	0.0%
	<70 mg/dL	3.1%
	70 mg/dL-180 mg/dL	64.9%
	>180 mg/dL	32.0%
	>250 mg/dL	11.5%
	CV	0.44
Sensor	Sensor Usage	316.8days/97.1%



TAKE-HOME MESSAGES

• Hybrid closed-loop systems are not interchangeable; they share a goal but differ in behavior.
• Algorithm type, target flexibility, meal and exercise tools, and CGM-pump architecture shape the lived experience.
• The best prescription starts with a structured conversation about physiology, lifestyle, fears, and preferences.

Choose the system around the person, then train the person around the system.

DO-IT-YOURSELF

#WEARENOTWAITING

The Guardian

Experience: I built my own pancreas

ACM TECHNEWS

Hacking Diabetes: People Break Into Insulin Pumps as an Alternative to Delayed Innovations

Open Source Closed-Loop Insulin Delivery Systems: A Clash of Cultures or Merging of Diverse Approaches?

Journal of Diabetes Science and Technology
2018, Vol. 12(6) 1223–1226

DOI: 10.1177/1932296818792577
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- **OpenAPS**
- **AndroidAPS**
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