

# What Do Healthcare Professionals and People With Diabetes Know About Insulin Transport and Storage? A Multinational Survey

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## Keywords

Insulin, insulin storage, awareness, education, temperature

Previous research has shown that insulin, as a peptide hormone, is susceptible to structural changes and loss of effectiveness when exposed to environmental temperatures outside the recommended storage range.<sup>1-4</sup> It was also shown that it is often improperly stored by people with diabetes (PwD) to a clinically relevant percentage of storage time,<sup>5</sup> although the effect on glycemic levels remains not yet quantified.

To assess awareness and knowledge regarding proper storage and transport of insulin, we conducted a cross-sectional online survey (Charité ethics approval: EA 2/042/20). Participants were recruited via professional medical organizations, international patient advocacy networks, and social media. Of the 200 participants based in 16 different countries in Europe, North America, Asia, and the Western Pacific region, 74% were PwD, including type 1, 2, and other; 26% were healthcare professionals (HCPs); and 19% were caregivers of children with diabetes. As participants could belong to more than one group, 26 participants were HCPs living with diabetes and 10 were HCPs and caregivers of children with diabetes at the same time. An analysis was made by means of a spreadsheet analysis. Because we made some interesting findings, we would like to provide a brief summary of the results.

Only 54% of the participants could indicate the correct temperature ranges for both storage of unopened insulin in a refrigerator (2°C-8°C) and when opened and in use (2°C-30°C). Of PwD and caregivers, 76% take precautions to protect their insulin in-use from heat or cold, and 50% assume that insulin loses partial effectiveness when exposed to temperatures outside the recommended range. However, we found participants to overestimate the individual protection measures taken, as only 35% regularly monitor storage temperatures, and only 67% use a “cooling bag/dedicated cooler” to protect their insulin during travel.

One-third of all HCPs report having never received education on insulin storage as part of their professional

training, without significant differences between those working in diabetes care and other areas of healthcare.

Although all groups (45% of HCPs, 51% of caregivers, 33% of PwD) have experienced incidents with a loss of insulin effectiveness as a suspected cause for glycemic instability, or even emergency situations, those cases were not sufficiently documented and remain underreported. Noticed effects were mostly glucose fluctuations outside their target range and ineffective correction doses (46%) and exposure to heat (20%). Of the PwD and caregivers who suspected a correlation of insulin storage and efficacy, only 30% ever discarded their insulin and renewed their prescription to replace it. The suspected causes for out-of-range temperatures included, for example, having left insulin in a car in summer or winter and the use of heat blankets at night (Table 1). Of the HCPs that witnessed such incidents with their patients, 43% suspected exposure to heat or cold, the use of expired (17%), or otherwise incorrectly stored insulin (26%). However, only 42% of them documented such incidents and the suspected cause in the patient record, and only 8% included the information in their medical report or discharge letter. Only one participant consulted the insulin manufacturer.

Given the importance of precise insulin dosing and the financial burden on PwD and caregivers due to increasing insulin prices and out-of-pocket expenses, there is an



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**Table 1.** Answers From People With Diabetes and Caregivers of Children With Diabetes on How They Noticed a Loss of Their Insulin's Effectiveness.

Noticeable effect on glycemic levels (n = 43)	<p>“[. . .] after long time outside BG's where off”</p> <p>“Severely high blood sugars despite multiple set changes”</p> <p>“High Glucose, didn't work good”</p> <p>“High BG which did not respond to correction boluses.”</p> <p>“BG ran high. [. . .]”</p> <p>“Frequent unexplainable high BGL [. . .]”</p> <p>“High blood glucose values that did not respond to correction boluses for hours”</p> <p>“Blood glucose levels rose although the dose was adapted. [. . .]”</p> <p>“[. . .] My BGL was high and a new vial of insulin would not bring down the hyperglycaemia. When I luckily arrived the next day home from travel, new insulin from the fridge brought down the high BGL in 3 hours”</p> <p>“values did not change”</p> <p>“the effectiveness was set to half”</p> <p>“diabetic ketoacidosis”</p> <p>“High blood glucose values. It had less effectiveness.”</p> <p>“It had no effectiveness anymore. During the first hours it is difficult to trace it back to the insulin.”</p> <p>“Blood glucose values over 500mg/dl despite multiple boluses. [. . .]”</p> <p>“Insulin lost its effect, glucoses rose and would not come down. Refilling the cartridge with new insulin fixed the situation immediately. [. . .]”</p> <p>“severe ketoacidosis [. . .]”</p> <p>“too high values without change despite application of insulin”</p> <p>“Hyperglycaemia [sic!] despite giving correct insulin doses. [. . .]”</p> <p>“The insulin did not have the expected effectiveness anymore. Wrong storage.”</p> <p>“high BG, [. . .]”</p> <p>“Too high blood glucose values without an alternate explanation [. . .]”</p> <p>“High sugars and symptoms of dka”</p> <p>“bad effectiveness”</p> <p>“High BG”</p> <p>“It didn't correct my blood sugar when it was high”</p> <p>“My blood sugar rose and correcting had no effect. [. . .]”</p> <p>“My continuous glucose monitor informed me of rising glucose levels despite taking insulin.”</p> <p>“My bsl was constantly high. [. . .]”</p> <p>“High blood sugar that would not come down.[. . .]”</p> <p>“high BG, [. . .]”</p> <p>“Stubborn high blood glucose levels”</p> <p>“high blood sugar”</p> <p>“Blood sugars not acting as predicted”</p> <p>“The effectiveness clearly decreased.”</p> <p>“My son's BGL rose rapidly and did not come down despite large boluses”</p> <p>“[. . .] found my fiasp to be much less effective than usual [. . .]”</p> <p>“No effect, [. . .]”</p> <p>“High bg”</p> <p>“[. . .] I got hyperglycemic values. Insulin did not work as strongly as before anymore.”</p> <p>“[. . .] More recently, a change in sensitivity towards the end of a 6-week trip.”</p> <p>“[. . .] Didn't work well”</p> <p>“[. . .] As I used the insulin, I needed twice the amount of insulin. The other vial did not work at anymore at all.”</p>
Exposure to heat (n = 19)	<p>“Loss of power to refrigerator for 2 weeks”</p> <p>“I didn't end up using it, but I knew it had accidentally been left in extreme heat (42 degrees Celsius) so I discarded it.”</p> <p>“Knew it was hot”</p> <p>“[. . .] I left my insulin in my suitcase in a hot car for a few hours.”</p> <p>“Did not try it; discarded as a precaution because it had been left in very hot conditions for an extended period of time.”</p> <p>“It got too hot. [. . .]”</p> <p>“Was stored for more than 30 days in a room at 25-30°C outside. [. . .]”</p>

(continued)

Table 2. (continued)

	<p>“Used to live in Florida after long time outside [. . .]”</p> <p>“[. . .] Happened [. . .] in hot, pump and tube were exposed to direct sun light for a long time. [. . .]”</p> <p>“[. . .] Camping in southern Europe, no cooling possible for several days.”</p> <p>“[. . .] was in the heat”</p> <p>“[. . .] because of heat.”</p> <p>“[. . .] I had used an electric blanket to keep warm in winter and the insulin in my pump was kept too warm overnight because I forgot to switch the heat off before I fell asleep.”</p> <p>“[. . .] during summer vacation the insulin probably became too warm despite protective measures”</p> <p>“[. . .] e.g. after swimming in very warm water/ pump unprotected in the sun”</p> <p>“[. . .] I had been out on a 100 degree day for several hours.”</p> <p>“[. . .] I was travelling in a very warm climate and not refrigerating my insulin.”</p> <p>“[. . .] On another occasion after returning from a few days on a beach holidays [. . .], it probably overheated on the beach.”</p> <p>“[. . .] too high solar radiation”</p>
Exposure to cold (n = 17)	<p>“Incorrectly stored and frozen in the fridge”</p> <p>“Didn't even try. It was frozen by a B&amp;B fridge. . .”</p> <p>“Forgot the insulin in the car in the winter, frozen solid, not injectable at all, frozen insulin loses all effect. Warm gradually degrades”</p> <p>“It was frozen.”</p> <p>“Frozen by accident”</p> <p>“Our refrigerator was frozen and at noticed [sic!] it too late. [. . .]”</p> <p>“[. . .] too cold temperature”</p> <p>“Hotel fridge too cold”</p> <p>“I saw the person take it out of the freezer”</p> <p>“insulin was frozen”</p> <p>“due to wrong storage frozen on the back to the fridge”</p> <p>“It has been forgotten in the freezer.”</p> <p>“[. . .] Probably often stored incorrectly in pharmacy locks, due to sub-zero temperatures in winter”</p> <p>“A few times when insulin had been frozen [. . .]”</p> <p>“[. . .] wearing pump on a belt and outside temperature -10 °C. With a new vial from the fridge everything worked fine again.”</p> <p>“[. . .] after low temperatures (in my coat pocket at -20c). [. . .]”</p> <p>“[. . .] Once in cold.”</p>
Visible changes (n = 14)	<p>“I did not use the insulin any longer. Small, white flakes had formed.”</p> <p>““Floaters”. [. . .]”</p> <p>“flakes”</p> <p>“It became opaque”</p> <p>“[. . .] it developed a ‘stringy’ look to it”</p> <p>“Had a cartridge get cloudy [. . .]”</p> <p>“It was opaque”</p> <p>“flaky structure”</p> <p>“flaky parts”</p> <p>“flaky”</p> <p>“cloudy”</p> <p>“It formed flakes.”</p> <p>“[. . .] more viscous”</p> <p>“appearance [. . .]”</p>

urgent need for more transparency of publicly available information on insulin stability and the impact of potentially harmful environmental factors as well as sufficient recommendations for daily practice. Based on published research to date, it was not possible to precisely quantify the potential decline of insulin potency caused by environmental temperature. However, this lack of knowledge and

awareness can put PwD at risk of variations of glucose levels with an increased risk for severe consequences such as diabetic ketoacidosis. Participants appear to employ a variety of individual protection measures, which are often not appropriate, that is, reported measures like wrapping their insulin in a wet cloth or storing insulin on ice packs or ice cubes.

Because of the considerable number of participants who were not informed about the correct storage conditions and the potential structural changes, there is a need for better education of HCPs, PwD, and caregivers to prevent incidents in the future, reduce unnecessary waste of insulin, and allow safe and efficient diabetes management. Furthermore, research is needed to investigate this anecdotal correlation of temperature and insulin stability reported by the users, as those cases seem to rarely be documented.

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