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Sick day management in children and adolescents with diabetes

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This article is a chapter in the *ISPAD Clinical Practice Consensus Guidelines 2014 Compendium*. The complete set of guidelines can be found for free download at www.ispad.org. The evidence grading system used in the ISPAD Guidelines is the same as that used by the American Diabetes Association. See page 3 (the Introduction in *Pediatric Diabetes* 2014; 15 (Suppl. 20): 1-3).

Executive summary and Recommendations

- The diabetes care team should provide clear guidance to patients and families on how to manage diabetes during intercurrent illnesses as well as how they or other emergency medical personnel can be reached (diabetes team telephone contacts, mobile telephones, emergency medical assistance procedures) and such education should be repeated periodically to avoid the complications of:
  - ketoacidosis
  - dehydration
  - uncontrolled or symptomatic hyperglycemia
  - hypoglycemia
- Never completely stop insulin (A)
- When vomiting occurs in a child or adolescent with diabetes, it should always be considered a sign of insulin deficiency until proven otherwise (E)
- The insulin dose usually needs to be increased when there is fever or with most general or respiratory illnesses based on knowledge of symptoms and signs especially knowledge of ongoing monitored blood glucose (BG) and/or urine or blood ketone levels (E):

1 Elevated BG with an absence or only small amount of ketones:
   - Give 5–10% of the total daily dose (TDD) of insulin (~0.05–0.1 U/kg) as short or rapid-acting insulin subcutaneously or intramuscularly and repeat this same dose every 2–4 h according to BG response and clinical condition. TDD of insulin is the sum of all long, intermediate and short/rapid-acting insulins usually taken.

2 Elevated BG with moderate or large amount of ketones is more serious and reflects actual or impending diabetic ketoacidosis (DKA) with potential for coma or death:
   - Give 10–20% of the TDD of insulin (~0.1–0.2 U/kg) as short or rapid-acting insulin subcutaneously or intramuscularly and repeat this same dose every 2–4 h according to BG response and clinical condition.

- Insulin doses may need to be increased considerably in children who are in the partial remission phase, often up to 1 U/kg (E).
- Blood ketones are preferred over urine ketones when available and affordable, and the use during illness can reduce emergency room visits and hospitalizations (B).
- Strive for a BG between 4 and 10 mmol/L (70–180 mg/dL) and blood ketones below 0.6 mmol/L when the child is ill (E).
- The insulin dose often needs to be decreased when there is gastroenteritis, but should not be lowered to the extent that ketones are produced (E).
- In a child or adolescent with an intercurrent illness, URGENT specialist advice must be obtained when (E):
  - the underlying condition is unclear, fever persists, or family members are uncomfortable providing home care for any reason
  - weight loss continues suggesting worsening dehydration and potential circulatory compromise
  - vomiting persists beyond 2 h (particularly in young children)
  - parents are unable to keep BG above 3.5 mmol/L (60 mg/dL)
  - BG continues to rise despite extra insulin
  - fruity breath odor (acetone) persists or worsens
  - ketonuria is heavy and increasing/persistent or blood ketones are >1–1.5 mmol/L
  - the child or adolescent is becoming exhausted, confused, hyperventilating (? Kussmaul breathing) or has severe abdominal pain
  - change in neurologic status, mental confusion, loss of consciousness, seizures, progression of confusion may indicate impending or present cerebral edema; and treatment of cerebral edema is a medical emergency requiring immediate assistance with advanced medical facilities to prevent morbidity and mortality
  - the child is very young (<2–5 yr)
  - diabetes is not the only diagnosis, e.g., concomitant Down Syndrome or other mental illness, epilepsy, malaria, parasitic infections etc.
  - patients/relatives are exhausted or do not have the facilities or capability of providing needed care, e.g., intellectual, emotional and/or financial constraints, unavailability of insulin or any monitoring possibilities
  - caretaker understanding/language problems make it difficult to communicate with the family
  - if at any time the patient and/or adult caretakers request, emergency medical consultation should be facilitated including appropriate transport as possible according to the circumstances, ways to contact medical personnel and systems in place for initial sugar and electrolyte solutions to be started while awaiting emergency treatment and evacuation to higher level facilities.

Five General Sick Day Diabetes Management Principles:

- More frequent BG and ketone (urine or blood) monitoring
- DO NOT STOP INSULIN
- Monitor and maintain salt and water balance
- Treat the underlying precipitating illness
- Sick day guidelines including insulin adjustment should be taught soon after diagnosis and reviewed at least annually with patients and family members with a goal of minimizing and/or avoiding DKA and similarly minimizing and/or avoiding illness associated hypoglycemia.

The effects of illness on diabetes

Children and teenagers whose diabetes is under good metabolic control should not experience more illness or infections than children without diabetes. While there are very few well done controlled prospective studies about intercurrent illness in type 1 diabetes, one study of adult patients with type 1 diabetes reported a higher risk of urinary tract, bacterial skin, or mucous-membrane infections but upper respiratory-tract infections were no more frequent than in controls (1) There is some evidence of impaired leukocyte function in poorly controlled diabetes (2) and children with poor metabolic control may have altered immune function, increasing susceptibility to and delayed recovery from infection. One pediatric study found low IgG concentrations and reduction in complement protein 4, variant B (C4B) levels related to impaired metabolic control (3) and it is tempting to believe – but not scientifically validated – that chronic hyperglycemia might be associated with more problems. (4, 5). In many parts of the world pediatric and adolescent diabetes care is woefully inadequate because of a general lack of resources, lack of health care systems, and availability of care as well as the enormous costs of insulin. This all contributes to produce a state of chronic underinsulinization because insulin is simply too expensive or unavailable. As a result, chronic poor diabetes metabolic control exists. Prevention of DKA not only requires more insulin availability but also awareness of the increased risk of DKA, coma, and death associated with normal infections precipitating decompensation (5).

Some illnesses, especially those associated with fever, raise BG levels because of higher levels of stress hormones promoting gluconeogenesis and insulin

resistance (6). Illness often increases ketone body production due to inadequate insulin levels. In contrast, illness associated with vomiting and diarrhea (e.g., viral gastroenteritis) may lower BG with the increased possibility of hypoglycemia rather than hyperglycemia. Decreased food intake, poorer absorption, and a slower emptying of the stomach or overt diarrhea with more rapid transit during gastroenteritis may contribute to such hypoglycemia. Sometimes there are increased insulin requirements during the incubation period of an infection for a few days before the onset of the illness. The increased need for insulin may persist for a few days after the illness has passed presumably due to insulin resistance but all such descriptions are highly variable from one person to another and even from one illness to another. In the midst of a typical viral self-limited 'epidemic,' however, patterns may occur which facilitate making some generalizations from which advice for subsequent patients may be based.

More frequent monitoring

Glucose

- Frequent BG monitoring facilitates optimal management during illness (with adult supervision especially in adolescents)
- BG should be monitored at least every 3–4 h including through the night and sometimes every 1–2 h

Sick day preparation

- Urine glucose can still be utilized if BG testing equipment is not available (6).
- If routine BG testing is not available for any reason, then some emergency supplies should ideally be provided to be 'saved' for episodes of illness instead of for day-to-day monitoring according to appropriate individual local circumstances (7).
- Distinguishing those illnesses associated with hyperglycemia from those associated with hypoglycemia is facilitated by BG monitoring (5, 6, 8, 9).
- Insulin adjustments (sick day extra doses) and other insulin changes take place in direct relationship to the ongoing BG monitoring results (see below).

Ketones

Ketones are produced by the liver from free fatty acids that are mobilized as an alternative energy source when there is a lack of glucose for intracellular metabolism. Starvation ketones are produced when the BG is low. Ketones are also produced when insulin is lacking to initiate the transport of glucose from the blood stream into the cell. Ketones accumulate because of increased lipolysis, increased ketogenesis and decreased ketone body utilization due to low insulin levels. Urine strips measure acetoacetate (AcAc) and acetone itself while blood strips measure beta-hydroxybutyrate (BOHB). In acute ketoacidosis, the ketone body ratio (BOHB:AcAc) rises from normal (1:1) to 10:1 or more (10). In response to insulin therapy, BOHB levels commonly decrease long before AcAc levels do. The frequently employed nitroprusside test only detects AcAc in blood and urine and so routine urine ketone monitoring often shows prolonged ketonuria even when significant ketoacidosis and ketonemia have already responded to treatment (10). This results in some confusion at home because there seems to be more prolonged ketonuria compared to clinical improvement when sick day management has been successful; in hospital settings and emergency rooms, this may also produce the incorrect response of wanting more and more insulin to be given to 'clear' the ketones from the urine rather than understanding the physiology of what is metabolically taking place and what is actually being measured. Blood ketone testing helps to allow better understanding and therefore when to start to back down on aggressive extra insulin provision (5, 6, 9, 10).

Urinary ketone tests (liquid or test strips for acetone and AcAc levels) or, when available, blood ketone tests (for BOHB), help to guide sick day management. Blood ketone testing (measuring BOHB) provides additional information to urine ketone testing:

- Blood BOHB >0.5 mmol/L is abnormal in children with diabetes (11, 12).
- Adult studies have shown that the time delay after a pump stop to diagnosis of ketosis is significantly longer for ketonuria than for plasma ketonemia (13) and that a urinary ketone test can remain positive more than 24 h after resolution of an episode of ketoacidosis in over half of patients studied (14).
- There may be dissociation between urine ketone (AcAc) and blood BOHB concentrations which may be increased to levels consistent with DKA when a urine ketone test is negative or shows only trace or small ketonuria (5, 15).

Home measurement of blood BOHB concentrations in children and adolescents enables earlier identification and treatment of ketosis, when compared to urine ketone testing, and decreases diabetes-related hospital visits (both emergency department visits and hospitalizations) (16–18).

Blood BOHB measurements may be especially valuable to prevent DKA in patients who use an insulin pump as only rapid- or short-acting insulin is used in this type of therapy. Elevations in blood

BOHB may precede elevations in urine ketones due to interrupted insulin delivery (14) (e.g., catheter occlusion or dislodgement), which can rapidly lead to ketogenesis and ketosis as well as increased insulin needs associated with intercurrent infections.

- During resolution of ketosis, blood BOHB normalizes sooner than urine ketones (5). Monitoring BOHB may also have the potential to help prevent late hypoglycemia from overtreatment with insulin based upon the persistence of ketonuria at the same time the ketonemia is improving.
- Blood BOHB monitoring may be especially useful in very young children or when urine specimens are difficult to obtain.

Households should maintain readily available supplies and information for sick day management including:

- Written information on management and important contact numbers/addresses of health care team
- Telephone availability has been shown in several clinical studies to facilitate communication, allow for earlier advice and institution of sick day guidelines and decrease or minimize clinical decompensation and avoid emergency room use as well as decrease hospitalization rates (19–21).
- Sick day foods and hydration supplies such as chicken soup, broths.
- Sufficient glucose and ketone monitoring supplies, additional insulin and an emergency glucagon kit.

Never stop insulin

The insulin dose may need to be increased or decreased to maintain glucose metabolism.

- The most common mistake made by health care providers and caregivers who are unfamiliar with diabetes is to advise the complete omission of insulin because 'the child is ill and not eating,' thus increasing the risk of frank DKA. (5, 6, 8)
- Even in the fasting state, some insulin is still required for basal metabolic needs, which may go up during an acute illness situation so that more frequent monitoring of BG and ketones is required.
- Insulin doses may go up during an acute illness situation so that more frequent monitoring of BG and ketones is required.
- If episodes of hyperglycemia, ketosis, and vomiting recur, with or without infection, it should be recognized that this may be due to omission (22) or inadequate administration of insulin. Insulin omission is particularly problematic during adolescence (23) and almost always represents a severe psychosocial issue, ie. sexual or physical trauma, emotional trauma or abuse, poorly treated or unrecognized anxiety or depression, learning problems, executive dysfunction and/or attention deficit disorders or some combination. Family dysfunction frequently occurs under such circumstances and may contribute to the recurrence DKA episodes either directly or indirectly. (24) Lack of appropriate adult supervision needs to be considered with appropriate therapeutic interventions put into place since recurrent DKA has a high association with DKA-related complications including coma and death. (5, 6, 9, 10)

Loss of appetite

Replacing meals with easily digestible food and sugar-containing fluids provides energy (carbohydrates) and may help prevent further ketosis. Necessary sick day management supplies at home include the following:

- glucose tablets, sweets, or candies such as jelly beans or Lifesavers® as well as dried fruit to prevent hypoglycemia
- Clean (boiled/purified), cool water to provide hydration and prepare salty soups
- sugar and electrolyte containing fluids such as sports drinks, electrolyte mixtures, Pedialyte®, Kool-Aid® or even sugar-containing ginger-ale or colas to provide hydration, glucose, and salts
- easy to digest carbohydrates such as crackers or rice

Maintaining hydration with salt and water

- Hyperglycemia, fever, excessive glycosuria, and ketonuria all contribute to increased fluid losses.
- Sick day cabinets should contain supplies as above to prevent dehydration.
- Liquids for hydration should contain salt and water and not just plain water especially if there are ongoing losses associated with vomiting or diarrhea. Chicken soup or clear broths are an excellent source of not only water but also sodium salt and some potassium, all needed for assistance with maintenance of hydration as well as avoiding mineral and water imbalance in conditions leading up to DKA (5, 6, 8–10). If appetite is decreased or the BG is falling below 10 mmol/L (180 mg/dL), sugar-containing fluids should be considered to decrease starvation ketosis (e.g., sports/electrolyte drinks, pediatric electrolyte mixtures, diluted fruit drinks, colas, ginger ale, etc.) (5, 6, 8–10). It may be reasonable to remove excessive carbonation (bubbles) in some soft drinks to minimize any potential indigestion. This can be achieved by

opening the containers and allow time for bubbles to escape with a little bit of shaking/stirring as well (25).
- Elevated levels of ketones, whether associated with low BG (starvation) or high BG (insulin deficiency), contribute to nausea and vomiting and may lead to decreased food and fluid intake, further elevated levels of ketones and worse dehydration as well as (decompensated) ketoacidosis (5, 6, 9, 10).
- Especially in young children with diabetes, intravenous fluids may be required if nausea, vomiting or diarrhea are persistent and associated with ongoing weight loss in order to prevent cardiovascular collapse, hypotension, coma, and death (5, 6, 9, 10).

Specific medical advice: treat the underlying precipitating illness

The underlying illness should be treated as it would be for a child or adolescent without diabetes (i.e., antibiotics for bacterial infections but not viral infections) 5, 6, 9, 10. In some parts of the world, specific endemic or epidemic illnesses have to be considered [e.g., dengue hemorrhagic fever (DHF), malaria, gastrointestinal parasitic infections etc.]. Monitoring and clinical manifestations of these may be complicated in diabetes patients (8). Treating fever, malaise and headache with antipyretics or pain medications such as paracetamol, acetaminophen, or ibuprofen is acceptable but not mandatory.

  - Sick day home supplies can include enteral and rectal preparations for fever management.
  - Unknown or uncertain alternative medicine co-prescription should be avoided and, as part of education efforts, acknowledged and reviewed in advance and periodically thereafter.

- Vomiting may be caused by either:

  1 the illness itself (i.e., gastroenteritis, unclean food or food poisoning, surgical condition or other illness)
  2 low BG
  3 lack of insulin resulting in high BG and ketosis.

- Unless food poisoning is suspected, consider treatment of vomiting with single injection or rectal administration of anti-emetics (e.g., Ondansetron, Promethazine suppositories) to help oral intake of carbohydrate unless concerns about mental status exist. However, in the case of high BG and an excess of ketones, priority should be given to administering extra insulin as well as sufficient salt and water solutions. In this situation, the vomiting often stops once extra insulin has been given to reverse ketosis.
- Oral medicines for symptomatic relief of vomiting or diarrhea have no proven efficacy and are therefore not usually recommended. However, if available, loperamide or similar anti-diarrheal medication, bismuth subsalicylate® combinations may be used to help provide symptomatic relief (6).

Additional insulin

- Additional doses of short/rapid-acting insulin are required with careful monitoring to reduce BG, prevent ketoacidosis, and avoid hospital admission (5, 6, 8–10).
- Both rapid-acting insulin analogs as well as older, more traditional short acting insulin (synthetic or animal-origin) can be used to provide supplemental insulin during sick days depending upon availability and cost.
- The dose and frequency of injection will depend on the level and duration of hyperglycemia as well as the severity of ketosis. Such supplemental doses are usually given subcutaneously but may also be given intramuscularly with healthcare professional advice.
- If there is hyperglycemia with negative or small amounts of ketones, usual recommendations are to give an additional 5–10% of TDD of bolus and basal insulins added together to provide calculations for this supplemental (booster) dose (approximately 0.05–0.1 U/kg) as short/rapid acting insulin administered urgently and this supplemental sick day dose may be repeated every 2–4 h based upon BG monitoring results (see Table 1).
- If there is hyperglycemia and more marked ketonuria (moderate to high), usual recommendations are to give an additional 10–20% of TDD (approximately not more than 0.1 U/kg) as short-/rapid-acting insulin. This dose should be repeated every 2–4 h; based upon frequent glucose and ketone results (see Table 1), response to the supplemental dose, clinical status and hydration status.

The additional dose recommendation of 0.05–0.1 U/kg is a general recommendation for children and adolescents with standard insulin requirements of approximately 0.7–1 U/kg/day. However, for children or adolescents who have low usual daily insulin requirements or those with insulin resistance and high insulin requirements, the percentage (%) calculations may work more readily rather than the 0.1 U/kg empiric additional dose

- When patients in remission phase are ill (during 'the honeymoon phase') there may be a need to increase insulin up to 1 U/kg/day very quickly.

Table 1. How to calculate sick day booster fast acting insulin dosage (5, 7–10) [E]

How to calculate the Amount of Extra Insulin on Sick Days [E]. No data are available from clinical trials						
Ketones		Blood glucose				
Blood ketones mmol/L	Urine ketones	<5.5 mmol/L <100 mg/dL	5.5–10 mmol/L 100–180 mg/dL	10–14 mmol/L 180–250 mg/dL	14–22 mmol/L 250–400 mg/dL	>22 mmol/L >400 mg/dL
<0.6	Negative or trace	Do not give extra insulin. May need to consider minidoses of glucagon (see Table 2) if <4 mmol (70 mg/dL)	No need to worry	Increase dose of insulin for next meal if BG is still elevated	Give extra 5% of TDD or 0.05 U/kg	Give extra 10% of TDD or 0.1 U/kg. Repeat if needed
		Check BG and ketones again in 2 h				
0.6–0.9	Trace or small	Starvation ketones. Extra carbohydrates and fluid are needed	Starvation ketones. Extra carbohydrates and fluid are needed	Give extra 5% of TDD or 0.05 U/kg	Give extra 5–10% of TDD or 0.05–0.1 U/kg	Give extra 10% of TDD or 0.1 U/kg. Repeat if needed
1.0–1.4	Small or moderate	Starvation ketones. Extra carbohydrates and fluid are needed	Starvation ketones. Extra carbohydrates and fluid are needed. Give ordinary bolus dose	Extra carbohydrates and fluid are needed. Give 5–10% of TDD or 0.05–0.1 U/kg	Give extra 10% of TDD or 0.1 U/kg	Give extra 10% of TDD or 0.1 U/kg. Repeat if needed
1.5–2.9	Moderate or large	High levels of starvation ketones. Check BG meter. Recheck BG and ketones. Extra carbohydrates and fluid are needed	High levels of starvation ketones. Extra carbohydrates and fluid are needed. Give 5% of TDD or 0.05 U/kg. Repeat when BG has risen	Extra carbohydrates and fluid are needed. Give 10% of TDD or 0.1 U/kg	Give extra 10–20% of TDD or 0.1 U/kg. Repeat dose after 2 h if ketones do not decrease	
		May need IV glucose if child cannot eat or drink. Risk of developing ketoacidosis!				
		Check BG and ketones every hour				
≥0	Large	Very high levels of starvation ketones. Check BG meter. Recheck BG and ketones. Extra carbohydrates and fluid are needed	Very high levels of starvation ketones. Extra carbohydrates and fluid are needed. Give 5% of TDD or 0.05 U/kg. Repeat when BG has risen	Extra carbohydrates and fluid are needed. Give 10% of TDD or 0.1 U/kg	Give extra 10–20% of TDD or 0.1 U/kg. Repeat dose after 2 h if ketones do not decrease	
		There is an immediate risk of ketoacidosis if the blood ketone level is ≥3.0 mmol/L Insulin treatment is needed urgently! Consider evaluation of patient at emergency department				

BG, blood glucose; TDD, total daily dose.

To calculate the total daily dose (TDD), add up all the insulin given on a usual day (i.e., rapid-/shortacting + intermediate/long-acting) or sum of basal rate and boluses in a pump. Do not include additional boluses given for unexpected hyperglycemia. High blood glucose and elevated ketones indicate a lack of insulin. 'Starvation blood ketones' are usually below 3.0 mmol/L. When the child is feeling sick or vomits, and the BG is below 10–14 mmol/L (180–250 mg/dL, see table), he/she must try to drink sugar-containing fluids in small portions to keep the BG up. When ketone levels are raised, priority is to give extra insulin, and this will be difficult if BG is low. Extra insulin may be given as rapidacting insulin analogues or short-acting regular insulin, but rapid-acting if available is preferred. Short-acting insulin can be given intramuscularly to speed up absorption. The ketone level may increase slightly (10–20%) within the first hour after giving extra insulin, but after that it should decrease [E].

- During illness it also may be necessary to increase basal insulin doses whether by multiple injection therapy or when using an insulin pump. With a pump, temporary basal rate increases of 20% to as high as 50 or 100% may be used until the BG begins to normalize and the ketones clear based upon ongoing BG, ketone monitoring and clinical response.

Example: A sick child has BG 14–20 mmol/L (i.e., 250–360 mg/dL) with moderate urinary ketones and/or blood ketones of approximately 1.5 mmol/L. Advise 10–20% of total daily insulin dose (or 0.1 U/kg) as short/rapid acting insulin every 2–4 h until BG falls to <14 mmol/L (<250 mg/dL). Thereafter any additional doses might be 5–20% of TDD. Check urine ketones at every voiding. If available, check blood ketones and recheck hourly if elevated (>0.6 mmol/L).

- After extra insulin has been given, the blood ketone level may temporarily increase by 10–20% for the first hour or two but should be expected to decrease thereafter.
- Urine ketones often stay elevated for many hours because of the body's conversion of blood BOHB into AcAc which then can be measured with urine testing (5). Acetone can be stored in fat tissue during ketosis and, along with conversion of BOHB to AcAc, may contribute to persistent urine ketones despite interruption of total ketogenesis with insulin and fluid administration (5).

When ketone testing is not available

It is strongly recommended that some form of ketone testing be available, and urine strips are a relatively cheap investment. However, in some circumstances, no ketone testing may be available or affordable. In these situations it must be emphasized that during intercurrent infections, BG testing remains very important in helping to avoid worsening ketoacidosis and to prevent hospital admission as well as progression of DKA to coma and death (5, 6, 8). It is helpful to provide written advice on how much additional insulin to give for particular levels of BG (as in Table 1) or when body weight is not available to advise on particular extra doses of insulin according to the child or adolescent's age and usual TDD (8, 9). Periodic review and re-teaching should also be considered at least on an annual basis and actually documented in the medical records by staff.

Infections associated with hypoglycemia

- These infections are usually viral gastroenteritis diagnoses and are often associated with nausea and vomiting with or without diarrhea. Any illnesses associated with more gastrointestinal symptoms rather than respiratory symptoms would fall into this category. Advise replacing meals with frequent small volumes of sugary drinks that also contain sodium (salts) and maintain careful BG monitoring with consideration for temporary reduction (but not elimination) of insulin dosage (5, 6, 8–10).
- Do not give non-sugar fluids in this situation.
- Give sufficient fluids to maintain hydration. Keep records of how much the child has had to drink.
- Attention to urinary output and measurement of body weight at home every 4–6 h can serve as a guide to fluid needs. Steady weight suggests adequate hydration and fluid replacement whereas ongoing weight loss would usually require telephone or other contact with health care personnel to assess need for emergency room or hospital intravenous fluid treatment (5, 6, 8–10).
- Reduction of total daily insulin dose by 20–50% may be required if there is concomitant hypoglycemia and not hyperglycemia as indicated above (5, 6, 8–10) but if the doses are lowered too much, there is a risk of developing insulin deficiency leading to ketosis and ketoacidosis.

Table 2. Recommended dose for mini-dose glucagon [B]*

	Quantity			
Age (yr)	Ugm	mg	cc's (1 mg/cc)	Units on insulin syringe
<2	20	0.02	0.02	2
2–15	10 per yr of age	0.01 per yr of age	0.01 per yr of age	1 per yr of age
>15	150	0.15	0.15	15

Note that the doses recommended above are quite different (lower) from emergency doses given in case of severe hypoglycemia.

*Correction boluses to correct hyperglycemia can be given at any time or added to meal boluses. A useful guide to estimate correction doses is to employ the '100' rule (the TDD is divided into 100 to estimate the number of mmol/L that the BG will fall by giving 1 U of insulin) (24, 25) (C, C, and E). For mg/dL, use the '1800 rule', i.e., divide 1800 by the TDD. For example, for a patient on 50 U of insulin per day, the PG should fall by approximately 2 mmol/L (36 mg/dL) for each additional 1 U of insulin. During illness, the correction factor can be recalculated every day to match the increasing (or decreasing) insulin requirements. This calculation can also be used to estimate a negative correction to correct for hypoglycemia [in a patient on 50 U of insulin a day, giving 1 U less at meal times should allow the PG to rise by 2 mmol/L (36 mg/dL)].

- Check ketones regularly as a guide to determine that the child or adolescent has sufficient carbohydrate/sugar intake. Ketones associated with gastrointestinal illnesses and hypoglycaemia usually reflect inadequate energy supply rather than insulin deficiency (i.e., starvation ketones) but both reasons may occur in any individual situation.
- If hypoglycemia (<3.5–4 mmol/L, 65–70 mg/dL) and nausea or food refusal persists, a modified, smaller-than-usual glucagon injection – if available – may reverse the hypoglycemia and enable oral fluid intake to be re-established ('mini glucagon treatment') (26, 27) (see Table 2). Repeat after 1 h or more if needed. If hypoglycemia persists and glucagon is not available, emergency services will be required but simple sugar in the buccal cavity or honey or molasses may also be provided as long as there is a determination that there is no significant neurologic compromise where aspiration may occur.

Specific advice regarding sick day management on insulin pumps

The key points of sick day management, mentioned previously, are the same for pump users as for those on insulin injections (9, 28, 29). Patients on pumps use only rapid- or short-acting insulin and do not have any injected depot of long-acting insulin. With pumps DKA can develop rapidly with either interruption of insulin delivery or intercurrent illness to which there is no increased insulin response. Episodes of hyperglycemia must be taken very seriously especially if associated with positive urine and/or blood ketones. If the BG level is 14 mmol/L (250 mg/dL) or above in an insulin pump patient, the following steps should be taken:

- Immediately check for problems with the pump or delivery system and change the infusion set, tubing and reservoir of insulin. Kinks in the catheter, air in the infusion line, disconnected catheters especially at the insertion site or insertion site irritation all get identified when patient and family members are instructed to first change the infusion set and second, give an immediate injection by syringe or pen to be certain that insulin is being delivered.
- Check for ketones in the blood or urine.
- Proceed as directed in Table 3 depending on ketone result. In case of ketosis, extra insulin should always be given with a pen or syringe, not with

Table 3. Management of sick days and hyperglycemia with insulin pump (8) [E]

Ketones negative	Blood ketones >0.6 mmol/L or positive urine ketones or apparent that pump is not working or catheter blocked, dislodged etc.
Give correction bolus with pump Test BG hourly to confirm that BGs move downward	May be a pump delivery or site problem or an illness **Give sick day bolus by injection with pen or syringe** using Table 1 guidelines for sick day booster 5–10–20% rule
Drink low-carbohydrate fluids or salty liquids (i.e., soup) If BG lower after 1 h, recheck again in 1–2 more hours to decide if another bolus is needed If BG not lower on recheck, then **give bolus by syringe or pen** and follow instructions in second column	**Change the catheter and check to be sure pump is working** Continue to follow sick day booster guidelines using pen or syringe until BGs respond Re-establish insulin pump infusion with new set and cannula with temporary basal rate increase of approximately 120–150% depending upon BG and ketone results Monitor BG hourly and recheck ketones and weight at least every 4 h Drink extra high-carbohydrate fluids if the ketones are elevated and BG is low and extra low-carbohydrate 'diet' fluids if BG is elevated with or without elevated ketones If after 2 h there is no improvement, liaise with diabetes pump team If after 2 h the BG is improved, use the unused bolus rule to decide if an additional bolus is needed.* Pump use can be resumed BG remains high, ketones persist, or nausea, vomiting, or abdominal pain develop, confusion or problems staying awake and alert, contact the diabetes pump team or proceed to immediate hospital assessment

BG, blood glucose; TDD, total daily dose.
*Correction doses given for hyperglycemia should take into consideration the residual effect of any previous meal or correction bolus dose. A useful guide is to use the 'unused bolus rule' (approximately 30% of a rapid-acting insulin bolus is absorbed each hour). The correction dose should be reduced accordingly. For example, if 5 U had been given as a meal bolus 2 h previously, 60% would have been absorbed and the remaining 40% or 2 U would still be exerting an effect. This should be subtracted from any correction dose. However, most pumps have this 'insulin on board' included in the 'bolus guide', and you need then not subtract it manually if this function is activated.

the pump (as malfunction may be the cause of ketosis).
- To overcome insulin resistance, the basal rate may be increased from 120% to 150% according to BG and ketone results and, at the same time, correction boluses also may need to be increased by 10–20% during the period of illness.
- Meal insulin boluses may need to be decreased when the hyperglycemia has been corrected because patients may be eating less and their gastrointestinal absorption may be poor during the illness. Hypoglycemia should be treated in the usual way. The basal insulin rate may also need to be decreased if the BG still tends to be low provided the ketones continue to be negative.

Conflicts of interest

B. O.: advisory boards for NovoNordisk and Medtronic speaker's fees, honoraria and research grants from Medtronic, NovoNordisk, and Sanofi. D. J.: funding from ESPE. H. P. consultant for Sanofi. L. L.: funding from Abbott Diabetes Care, honoraria, grants and/or advisor or consultant for research from the NIH, Helmsley Trust, Medtronic, Omnipod, Lilly, NovoNordisk, Johnson and Johnson, Bayer Roche, Menarini, Boehringer Ingelheim, sanofi-aventis and DexCom. S. J. B.: honoraria or speaker's fees from Eli Lilly, Novo-Nordisk, CDiC, Life for a Child, Minimed Medtronics, LifeScan, Genentech, Serono, Teva Pharmaceuticals; and has received research grants from Eli Lilly, Novo-Nordisk, NIH, SelfCare, Inverness Medical, Medical Foods, Abbott-Medisense, LifeScan/Johnson and Johnson, Genentech, Pharmacia, Bristol-Squibb Myers, Pfizer, Becton-Dickenson and Serono. He is the owner of the New England Diabetes and Endocrinology Center (NEDEC) and President of New England Diabetes and Endocrinology Research Fund, Incorporated (NEDERF, Inc.). R. H.: speaker's honoraria and/or advisory board for NovoNordisk, Lilly, Sanofi, Medtronic, Roche, Menarini, Abbott and Unomedical. W. W. R. L.: speakers honoraria and/or advisory boards for Lilly, NovoNordisk, Sanofi, Medtronic, Abbott.

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