Acta Diabetol (2017) 54:1–8
DOI 10.1007/s00592-016-0907-4

REVIEW ARTICLE

Clinical review: the misreporting of logbook, download, and verbal self-measured blood glucose in adults and children with type I diabetes

Miranda Blackwell[1] · **Benjamin J Wheeler**[1,2]

Received: 24 June 2016 / Accepted: 26 August 2016 / Published online: 7 September 2016

Abstract Despite advances in technology, the frequent self-measurement of blood glucose (SMBG) remains fundamental to the management of 1 diabetes mellitus (T1DM). Once measured, SMBG results are routinely reported back to health professionals and other interested parties, either verbally, via a logbook, or electronically downloaded from a pump or meter. The misreporting of SMBG using various techniques represents a classic non-adherence behavior and carries with it both acute and chronic dangers. In addition, while this behavior appears very prevalent, many aspects remain largely unstudied. With this in mind, we aimed to summarize literature addressing the misreporting of SMBG in T1DM via a detailed literature search. This produced both recent and past literature. While most of these studies examined the prevalence of deliberate misreporting in a verbal or logbook context, others focused on the motivations behind this behavior, and alternative forms of misreporting, including deliberate manipulation of meters to produce inaccurate results and true technological errors. This timely review covers all aspects of misreporting and highlights multiple patient techniques, which are clearly adapting to advances in technology. We believe that further understanding and attention to this aspect of adherence may lead not only to improvements in glycemic control and safety, but also to the psychological well-being of those affected by type 1 diabetes.

Keywords Type 1 diabetes mellitus · Self-measured blood glucose · Misreporting · Self-management · Adherence

Introduction

The importance of glycemic control for both the short- and long-term health of people with type 1 diabetes mellitus (T1DM) has been clearly established [1, 2]. This has led to intensive insulin therapy becoming the standard of care in most centers. Fundamental to intensive therapy is the monitoring of blood glucose. This has evolved considerably over the years. Starting with the "water tasting" of the eleventh century [3], things have fortunately progressed, with the first blood glucose meters introduced in the 1970s and 1980s. From here, technology has continued to advance, with today's modern blood glucose meters showing significant improvements in accuracy and precision; sample size requirements; and analysis time. In addition, features such as alarms, memory storage capabilities, computer/clinic downloading, direct input into insulin pumps, and more recently hybrid meter/continuous glucose monitoring system (CGMS) technology, all facilitate frequent self-measurement of blood glucose (SMBG) and the application of these data into day-to-day management.

SMBG is not only essential for day-to-day monitoring, safety, and dose adjustment, it is also associated with improved glycemic control, with suggested improvements in HbA1c of up to 0.5 % (5.5 mmol/mol) with each additional SMBG to a maximum of 5–6/day [4, 5]. This may translate into long-term health benefits such as a

Managed by Massimo Porta.

✉ Benjamin J Wheeler
Ben.wheeler@otago.ac.nz

1 Department of Women's and Children's Health, University of Otago, PO Box 913, Dunedin 9054, New Zealand

2 Paediatric Endocrinology, Southern District Health Board, Dunedin, New Zealand

potential reduction in long-term diabetes complications. These positive impacts on glycemic control are likely multifactorial, potentially reflecting the benefits of a more intensive insulin regimen, but also indicating overall improvements in general diabetes self-care and self-determination.

However, SMBG still represents a large health burden for those affected by diabetes and therefore is likely to be a surrogate marker for overall adherence (or not) with one's diabetes management. Non-adherence with SMBG can occur in a number of ways. While a reduced frequency of SMBG is the simplest form of non-adherence, the intentional misreporting of SMBG to parents/caregivers and health professionals represents another much more complex aspect. This can take various forms, including (1) verbal misreporting, usually between a child and their parent, teacher, and/or health professional (e.g., at diabetes camp) and (2) various forms of logbook misreporting, traditionally in written form, but more recently occurring electronically, including the direct manipulation of pump download data. Regardless of type, this misreporting can result in both acute and chronic dangers, including hypo- and hyperglycemia.

Considering how critical SMBG is for management, glycemic control, and safety in T1DM, misreporting behavior has received relatively little attention in the medical literature. This review, therefore, aims to explore the current literature addressing the misreporting of SMBG in type 1 diabetes.

Methods

PubMed® (National Library of Medicine, Bethesda, MD, USA) and CINAHL® (Cinahl Information Systems, Glendale, CA, USA) were used to perform literature searches. The search strategy is as follows: (((((reliability) OR accuracy) OR compliance) OR adherence) OR performance) AND ((((reported) OR self-reported) OR self-reporting) OR reporting) AND ((blood glucose) OR blood glucose results) AND ((((monitoring) OR measuring) OR reading) OR self-monitoring) AND (((children) OR adolescents) OR adults). Results were limited to English language publications, and no time limit was applied. This yielded 332 results from PubMed® and 85 results from CINAHL®. Articles were selected first by title, then abstract, and full text if necessary. This yielded eight relevant papers. Additional hand searches were performed on reference lists where appropriate, producing one more paper. A less structured literature search related to more general aspects of T1DM and adherence was also performed.

The misreporting of SMBG

As discussed above, a major source of inaccuracy in SMBG is the deliberate misreporting of the meter reading by the patient. This misreporting of SMBG, primarily to parents/caregivers and health professionals, represents a classic non-adherence behavior. The literature examining this behavior is summarized in Table 1, and specific variations of misreporting are highlighted in Table 2.

Misreporting in adults

The first work investigating the prevalence of this behavior was conducted in 1984 [6]. It compared SMBG written logbook entries in 19 adults with T1DM to measurements taken and electronically stored by their meters. At this time, meter memory was a new technological development and participants were unaware of this capability. The main finding was that 75 % of participants misreported their blood glucose level (BGL) over the course of the study, mostly by reporting a lower BGL than actually recorded in order to portray a more "favorable" profile; however, episodes of hypoglycemia were also intentionally obscured. In addition, approximately 40 % of logbook entries could not be found in their corresponding meter and were termed "phantoms." These "phantom" readings represent the most common form of misreporting in all available studies.

In the following year, the same research team performed a similar study, but the 20 adult participants with T1DM were made aware of their meters' memory capabilities [7]. The aim of this study was therefore to investigate whether prior awareness of future logbook surveillance would impact upon the prevalence of SMBG misreporting. As a consequence, phantom readings were only 1 % of total SMBG reports, a significant reduction from the previous study ($p = 0.0027$). This appeared to take advantage of the Hawthorne effect, which states that when study participants know they are being observed, their behavior alters [8]. This technique has been successfully utilized in two additional pediatric studies, which will be discussed in more detail below [9, 10]. Subsequent logbook studies have supported these overall findings, with 47–55 % of study participants having some form of discrepancy between their SMBG and logbook entries [7, 11, 12], with phantom readings by far the most common form of misreporting.

Misreporting in children and adolescents

While less examined, data do exist for children and adolescents, and as one might postulate, due to psychosocial aspects of the teenage years, the prevalence of written

Table 1 Summary of published literature examining the misreporting of blood glucose levels

References	Participants	Design	Findings
Mazze et al. [6]	19 T1DM Adult—18–41 years	Written logbook versus meter memory Concealed study design—no participant awareness of meter examination Duration: 12–14 days	Misreporting in 67 % of participants Overall: 10 % of meter values omitted, 40 % of logbook entries phantom, and 26 % of remaining logbook entries different to their corresponding meter readings Mean BGL lower for logbook compared to meter
Mazze et al. [7]	20 T1DM Adult—14–41 years	Written logbook versus meter memory Participants aware of meter examination Duration: 6 weeks	Misreporting in 15 % of participants Overall: 7 % of meter values omitted, 0.5 % of logbook entries phantom, 1 % of logbook entries different to corresponding meter readings Improvement in performance from Mazze et al. [6] statistically significant.
Gonder-Frederick et al. [11]	30 T1DM Adult—21–66 years	Written logbook versus meter memory Concealed study design—no participant awareness of meter examination Duration: 2 weeks	Misreporting in 53 % of participants, in more than 10 % of their total reports Overall: 16 % of logbook entries incorrect, 10 % of meter values omitted, 5 % of logbook entries phantom
Kalergis et al. [12]	60 T1DM; 45 T2DM Adult—18–65 years	Written logbook versus meter memory Participants aware of meter examination Duration: two separate 2-month periods	Period 1 (no awareness of impending meter examination): 45 % of meter values omitted, 44 % of logbook entries phantom Period 2 (aware of impending meter examination): 8 % of meter values omitted, 5 % of logbook entries phantom Overall, logbook misreporting did not demonstrate a more favorable BGL profile
Wilson and Endres [10]	18 T1DM Child—12–18 years	Written logbook versus meter memory Initially concealed study design followed by full participant awareness Duration: two separate 6-week periods	Misreporting in 89 % of participants for period 1; 50 % in period 2 Period 1: 18 % of meter values omitted, 40 % of logbook entries phantom, 26 % of logbook entries different to corresponding meter readings Period 2: 8 % of meter values omitted, 16 % of logbook entries phantom, 6 % of logbook entries different to corresponding meter readings Improvement in performance between the two periods statistically significant
Chae et al. [14]	20 T1DM Child—13–18 years	Verbal report to health professionals versus meter memory Concealed study design—participants not aware of meter examination Duration: 3 days	Misreporting in 70 % of participants Overall: 13.5 % of verbal reports incorrect, 7.6 % of logbook entries phantom, 6 % of logbook entries different to corresponding meter readings No predictors of misreporting evident, including HbA1c
Sjoeholm et al. [9]	26 T1DM Child—13–18 years	Verbal report to health professionals versus meter memory Intervention: participant aware of impending meter examination, and comparison made to historical controls (Chae et al.) Duration: 3 days	Misreporting in 34 % of participants (compared to 70 % Chae et al.) Overall: 4.7 % of verbal reports incorrect, 2 % of logbook entries phantom Improvement in accuracy compared to Chae et al. statistically significant To date, lowest documented rate of misreporting
Guilfoyle et al. [13]	143 T1DM Child—13–18 years (90 participants who provided meter for analysis)	Verbal report of SMBG frequency versus actual meter frequency Relationship between reported frequency, glycemic control, and depression examined Participants aware of meter examination Duration: 3 months	Meter download most accurate representation of SMBG frequency, followed by parental report Adolescent self-report of SMBG frequency least accurate No examination made of actual BGL values

Table 1 continued

References	Participants	Design	Findings
Blackwell et al. [18]	15 T1DM Child—12–19 years	Qualitative study—interviewing teenagers with T1DM about their motivations for misreporting.	Different motivations for misreporting identified, including many which stem from the reactions of others to suboptimal BGLs Key motivations separated into three main themes: achieving benefits, avoiding negative consequences, and avoiding worry/concern in others or self

T1DM type 1 diabetes mellitus, *BGL* blood glucose level, *SMBG* self-measured blood glucose

Table 2 Misreporting by type, in order of descending frequency

Type of misreport	Description	Possible implications
Phantom	Patient-reported BGL not present in meter download	Classic non-adherence behavior Reduced SMBG frequency linked to unhealthy glycemic control Variable impact on insulin dosing, although most likely to result in under-administration
Reported BGL < Meter BGL	Fabricates hypoglycemia or conceals hyperglycemia	Potential for inappropriately low insulin dosing, and/or inappropriately high carbohydrate intake Appearance of hypoglycemia when none exists
Reported BGL > Meter BGL	Conceals hypoglycemia or fabricates hyperglycemia	Acute danger from concealing hypoglycemia, particularly in context of exercise Potential for inappropriately high insulin dosing, and/or inappropriately low carbohydrate intake (particularly in the context of hypoglycemia)

BGL blood glucose level, *SMBG* self-measured blood glucose

logbook misreporting appears even higher. The first study, in 1985, examined logbook misreporting in 18 teenagers [10]. This study had two sequential aspects. In the first, the participants were unaware of their meters' memory function, followed by the second, in which they were told that their meters memory would be compared to their logbook records. In the first study period, 88 % of participants had phantom reports, making up 40 % of all readings. Once aware of surveillance, misreporting did improve, from 88 to 50 % of all participants, but clearly this was not to the same degree as that seen in adults [7].

In a slightly different take on the theme, Guilfoyle et al. [13] investigated the accuracy of reported SMBG frequency, but not the actual SMBG values. Their main findings were that caregiver-reported SMBG frequency predicted glycemic control in the absence of meter download data ($p < 0.001$), that caregiver estimate of daily frequency was more accurate than the teenagers' self-reported SMBG frequency, and that both were over estimates of actual testing frequency.

More recently, verbal misreporting has been examined in two publications. Both of these took place in the context of adolescent diabetes camp, an environment where verbal reporting to health professionals is common. In the first, camp staff kept a record of verbally reported blood glucose levels for 3 days, and at the end of the camp, the participants' meters were downloaded without their prior knowledge. This study found that 14 % of verbal reports were inaccurate and 70 % of participants had discrepancies between their verbal reports and meter readings [14]. Similar to all other studies, phantom values were the most common form of misreporting at 8 % of total values or 56 % of misreported values. In a follow-up study, the adolescent participants were aware that their meters would be downloaded and compared to their verbal reports at the end of camp [9]. This simple intervention halved the number of participants who misreported and reduced the total misreporting rate to 4.7 %, from 14 % previously. In addition, this intervention significantly reduced phantom readings from 8 % of all values in the first study, to 2 % ($p < 0.001$).

From these studies, verbal misreporting appears less common than logbook misreporting. One could speculate that the face-to-face interaction of reporting verbally reduces misreporting. However, no studies have been conducted in adults, nor assessing the accuracy of verbal reporting of SMBG to parents or caregivers in the home setting. It remains uncertain how common misreporting would be in these circumstances.

Finally, of increasing importance in the modern era are electronic forms of logbook, such as pump or meter downloads. It should be noted that no studies to date have specifically looked at misreporting in this context. However, pump users clearly also misreport, as seen in both the verbal SMBG papers previously described [9, 14]. In these, insulin regimen (either multiple daily injections or insulin pump) was not predictive of misreporting behavior, with misreporting found equally in both groups. In addition, we anecdotally report that in our clinics misreporting is regularly found in electronic pump downloads. Further study and quantification of this behavior in the modern context is clearly warranted.

Manipulation of meter readings

Besides the misreporting methods described above, a range of other methods can be utilized either intentionally or unintentionally to alter the accuracy of meter readings. Potential techniques include using incorrect meter settings or dates [15]; tampering with the test strip or inserting it incorrectly [16]; diluting the sample with water or saliva; testing on someone or something else rather than one's own blood, i.e., control solution or someone without diabetes [10]; and under-loading the test strip (e.g., insufficient blood) [17]. While the existence of these behaviors is generally accepted, little literature exists specifically examining it.

Predicting and reducing SMBG misreporting or manipulation

A logical first step in reducing these behaviors is investigating what factors are predictive for them. Non-adherence is often implicated in unhealthy glycemic control; however, to date it remains uncertain whether HbA1c—arguably the most obvious potential predictor of misreporting, is a valid predictor of this behavior, and in general nothing appears associated with higher rates of error [6, 9, 11, 14], including HbA1c, insulin regimen, age, sex, and socioeconomic status. For example, one study described a participant who had appropriate metabolic control but had fabricated over 75 % of their logbook entries. Considering the generally small sample size of all these studies, further study in larger samples would be ideal.

Another logical step in reducing these behaviors is considering the motivations behind them. A number of papers have included speculations on motivation, including presenting a more favorable blood glucose profile; not wanting to interrupt an activity to test; not wanting testing to interfere with social situations; falsely misreporting hypoglycemia in order to access food or sweets; not wanting to be frequently reminded of diabetes by testing; and wanting to please their medical team or others with healthy readings and/or good adherence [10, 12, 14].

Table 3 Potential motivations for the misreporting of SMBG [18]

Motivation	Examples
To achieve a potential benefit	Gain food/sweets/lollies
	Be excused from school activities/examinations
	Continue doing an activity uninterrupted, e.g., sport
	Maintain personal autonomy
To avoid a negative consequence	Avoid adult censure or interference
	Avoidance of diabetes clinic
	Avoid perceived embarrassment
	Fear of missing out
To avoid worry/concern in others or self	Avoidance of emotional distress in others
	Avoidance of emotional distress in self

In addition, one recent qualitative study [18] has directly investigated the motivations behind this behavior by interviewing 15 teenagers with T1DM. Many instances of misreporting were described, with various underlying motivations identified and sorted into three major themes. These themes with examples are summarized in Table 3. In addition, participants of this study were asked what they perceived could help reduce their misreporting behavior and its impact on them. Two main suggestions were provided: (1) Some participants stated they would misreport less if their parents or medical team did not have such negative reactions (or patient-perceived negative reactions) to suboptimal BGLs—for example, if they did not feel they would get in trouble or be "told off" for having elevated or out-of-target BGLs. This last point is particularly important, suggesting that negative reactions to blood glucose, be it anger, worry, or panic (in parents/family or healthcare professionals) are a common motivating factor for misreporting, so efforts to reduce this or its perception are a logical first step in reducing misreporting; (2) others suggested having parents or the medical team check meter readings against electronic downloads more often in order to catch misreporting. However, views were polarized on this strategy, with some stating additional interference may exacerbate the problem.

This strategy of meter downloading is particularly relevant in the current environment, where meter downloads have already replaced traditional logbooks and self-recorded records for many (particularly for those on injection therapy). However, it needs to be noted that this does not solve blood glucose adherence issues for diabetes. While the opportunities for misreporting may decrease with direct meter downloads, other forms of meter manipulation (as discussed above) and non-adherence via simply reducing the frequency of SMBG will persist and potentially become more apparent over time as phantom values will cease to fill these electronic logbooks. In addition, given the increasing use of insulin pump therapy, until SMBG and/or patient-entered values into pumps are completely superseded by universal access to wireless technology and/or closed loop systems, misreporting may in fact be increasingly relevant in the coming years.

True technological error

While the above factors have all focused on intentional misreporting, a review on this subject is not complete without coverage of possible true technical errors, as these will also inevitably lead to inaccurate reporting. Modern blood glucose measurement systems are generally accurate, and current International Standardization Organization standards (ISO 15197:2013) for blood glucose monitoring systems require that 95 % of measurements must be accurate to within 0.83 mmol/L at lower blood glucose levels, and within 15 % at higher blood glucose levels [19]. A 2014 study of the accuracy of 12 blood glucose meters available in Germany found that 83 % were compliant with the ISO standards [20]. In other studies utilizing similar methods, 5/6 m tested [21], 3/3 m tested [22], and 2/2 m tested [23] were compliant with the current ISO guidelines, as well as a 2012 study which found that 27/34 systems were compliant with the 2003 version of the ISO guidelines [24]. The accuracy of meters is not just important for long-term glycemic control but also for short-term safety, with people whose meters consistently read “too high” having a higher risk of severe hypoglycemia [25].

The environment and circumstances of the test can also affect the accuracy of the reading. Classic examples of this include not loading enough blood into the test strip (under-loading), which can give a falsely low reading [17], and high altitude, which can give a falsely elevated value [26]. Environmental temperature and humidity, as well as patient temperature and blood flow can also cause inaccuracies, including underestimation of BGL [27]. The presence of certain other compounds at the test site or in the blood stream can also potentially be an issue, e.g., food residue high in glucose at the test site can falsely elevate readings [28], while the common pharmaceutical acetaminophen (paracetamol) has been known to alter readings [27]. There have also been questions over the accuracy of meters at very high altitudes, such as on planes. However, this does not appear to be a significant issue for modern meters, despite some individual cases of overestimation of blood glucose [29].

General diabetes adherence and adherence behavior in other conditions

It is surprising, given how vital SMBG is for day-to-day T1DM management, that so little has been published on SMBG adherence or lack thereof. However, due to the frequency of SMBG required in modern intensive therapy, adherence to SMBG is likely to be intimately connected to more global aspects of diabetes adherence. As general adherence to treatment in people with T1DM and other chronic conditions have been more widely studied, a brief coverage of these is a good way to conclude.

There are various practical factors which are likely to influence whether people are able to perform their recommended SMBG regimen, including the environment they are in, or how intense the activity they are performing is. However, there are also a more complex set of factors underlying adherence, such as an individual’s personality and attitudes, as well as established psychological factors such as cognitive distortions and stress [30]; coping mechanisms [31]; and various behavioral problems in adolescence [32].

Situational factors and the influence other people such as family and friends have on adherence have also been studied, revealing that the attitudes and reactions of others can have important effects on the behavior of a person with T1DM, or other chronic illness. In adolescents, social situations can impact negatively on adherence [33], particularly those where the adolescent perceives friends will react negatively to their illness/diabetes. Parental behaviors in childhood and adolescence also have a significant impact on adherence, with factors such as excess conflict, and less paternal involvement associated with lower adherence [34, 35]. The manner in which a parent (or health professional) reacts to reported health information is also likely to affect patient behavior, with behaviors such as yelling, scolding, or criticizing likely to negatively impact on whether a patient feels comfortable reporting accurately, as seen in the study examining misreporting motivations discussed above [18].

Michael Rapoff makes the point that adherence to treatment in chronic pediatric disease may worsen with a longer illness duration [36]. It is plausible that, in the context of T1DM, this might be due to patient complacency, or more likely burn-out from the constant daily requirements of their treatment regimen. In the same work, a systematic review of literature focusing on adherence in a variety of chronic pediatric diseases, it was found that children with HIV/AIDS had the highest rates of medication adherence, one theory behind this being the severe and imminent consequences of non-adherence for this disease. For T1DM, factors such as disease duration and the child’s perception of the consequences of non-adherence are likely to also be relevant. Arguably, the only chronic illness more prevalent than T1DM in children is asthma, and non-adherence with asthma therapies appears similar in frequency to T1DM, at 40–65 % of patients [37–39].

Finally, while tempting to blame patients for adherence failures, we as medical professionals should strive to avoid blame and closely examine our own behaviors and attitudes and reflect on the positive or negative impacts these may have on patient adherence. In addition, as stated by Cassel "Doctors do not treat chronic illnesses. The chronically ill treat themselves with the help of their physicians; the physician is part of the treatment. Patients are in charge of themselves. They determine their food, activity, medications, visits to their doctors—most of the details of their own treatment" [40].

Conclusions

Despite developments in technology, the reporting and self-measurement of blood glucose remains an essential aspect of modern diabetes management. The misreporting of SMBG is an important and understudied non-adherence behavior and involves multiple potential patient techniques, some of which are clearly adapting to advances in technology. Until the day comes when the regular self-measurement of blood glucose is no longer required, it is important for the diabetes clinic staff to be aware of misreporting, to define the individual's motivations for doing it, and respond and support accordingly. We believe that further understanding and attention to this aspect of adherence may lead not only to improvements in glycemic control and safety, but also to the psychological well-being of those affected by type 1 diabetes.

Compliance with ethical standards

Conflict of interest None.

Ethical standard This article does not contain any studies with human participants performed by any of the authors.

Informed consent None.

References

1. The Diabetes Control and Complications Trial Research Group (1993) The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. N Engl J Med 329(14):977–986. doi:10.1056/NEJM199309303291401
2. Writing Team for the Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Research Group (2003) Sustained effect of intensive treatment of type 1 diabetes mellitus on development and progression of diabetic nephropathy: the epidemiology of diabetes interventions and complications (edic) study. JAMA 290(16):2159–2167. doi:10.1001/jama.290.16.2159
3. Clarke SF, Foster JR (2012) A history of blood glucose meters and their role in self-monitoring of diabetes mellitus. Br J Biomed Sci 69(2):83–93. doi:10.3310/hta13150
4. Anderson B, Ho J, Brackett J, Finkelstein D, Laffel L (1997) Parental involvement in diabetes management tasks: relationships to blood glucose monitoring adherence and metabolic control in young adolescents with insulin-dependent diabetes mellitus. J Pediatr 130(2):257–265. doi:10.1016/s0022-3476(97)70352-4
5. Ziegler R, Heidtmann B, Hilgard D, Hofer S, Rosenbauer J, Holl R (2011) Frequency of SMBG correlates with HbA1c and acute complications in children and adolescents with type 1 diabetes. Pediatr Diabetes 12(1):11–17. doi:10.1111/j.1399-5448.2010.00650.x
6. Mazze RS, Shamoon H, Pasmantier R, Lucido D, Murphy J, Hartmann K et al (1984) Reliability of blood glucose monitoring by patients with diabetes mellitus. Am J Med 77(2):211–217. doi:10.1016/0002-9343(84)90693-4
7. Mazze RS, Pasmantier R, Murphy JA, Shamoon H (1985) Self-monitoring of capillary blood glucose: changing the performance of individuals with diabetes. Diabetes Care 8(3):207–213. doi:10.2337/diacare.8.3.207
8. McCambridge J, Witton J, Elbourne DR (2014) Systematic review of the Hawthorne effect: new concepts are needed to study research participation effects. J Clin Epidemiol 67(3):267–277. doi:10.1016/j.jclinepi.2013.08.015
9. Sjoeholm A, Grey A, Rayns J, Tomlinson P, Wheeler B (2016) Prior knowledge of blood glucose meter download improves the accuracy of verbal self-reported blood glucose in teenagers with type I diabetes at ski camp. Acta Diabetol 53:637–642
10. Wilson DP, Endres RK (1986) Behavioral pediatrics compliance with blood glucose monitoring in children with type diabetes mellitus. J Pediatr 108:1022–1024. doi:10.1016/S0022-3476(86)80955-6
11. Gonder-Frederick LA, Julian DM, Cox DJ, Clarke WL, Carter WR (1988) Self-Measurement of blood glucose. accuracy of self-reported data and adherence to recommended regimen. Diabetes Care 11(7):579–585. doi:10.2337/diacare.11.7.579
12. Kalergis M, Nadeau J, Pacaud D, Yared Z, Yale J (2006) Accuracy and reliability of reporting self-monitoring of blood glucose results in adults with type 1 and type 2 diabetes. Can J Diabetes 30(3):241–247. doi:10.1016/S1499-2671(06)03006-1
13. Guilfoyle SM, Crimmins NA, Hood KK (2011) Blood glucose monitoring and glycemic control in adolescents with type 1 diabetes: meter downloads versus self-report. Pediatr Diabetes 12(6):560–566. doi:10.1111/j.1399-5448.2010.00735.x
14. Chae M, Reith DM, Tomlinson PA, Rayns J, Wheeler BJ (2014) Accuracy of verbal self-reported blood glucose in teenagers with type I diabetes at diabetes ski camp. J Diabetes Metab Disord 13(1):14. doi:10.1186/2251-6581-13-14
15. Strumph PS (1990) ExacTech cheating. Diabetes Care 13(4):454. doi:10.2337/diacare.13.4.454b
16. Kruger DF, Basha KM (1989) Patient adjustment of blood glucose meter reading. Diabetes Care 12(6):438. doi:10.2337/diacare.12.6.438a
17. Pfützner A, Schipper C, Ramljak S, Flacke F, Sieber J, Forst T et al (2013) Evaluation of the effects of insufficient blood volume samples on the performance of blood glucose self-test meters. J Diabetes Sci Technol 7(6):1522–1529. doi:10.1177/193229681300700612
18. Blackwell M, Tomlinson PA, Rayns J, Hunter J, Sjoeholm A, Wheeler BJ (2016) Exploring the motivations behind misreporting self-measured blood glucose in adolescents with type 1

diabetes—a qualitative study. J Diabetes Metab Disord. doi:10.1186/s40200-016-0238-6

19. Geneva: International Organization for Standardization (2013) In Vitro diagnostic test systems—requirements for blood-glucose monitoring systems for self-testing in managing diabetes mellitus. DIN EN ISO 15197:2013
20. Freckmann G, Baumstark A, Schmid C, Pleus S, Link M, Haug C (2014) Evaluation of 12 blood glucose monitoring systems for self-testing: system accuracy and measurement reproducibility. Diabetes Technol Ther 16(2):113–122. doi:10.1089/dia.2013.0208
21. Pfützner A, Hengesbach C, Demircik F, Schipper C, Forst T, Musholt PB (2014) Performance of blood glucose meters in compliance with current and future clinical ISO15197 accuracy criteria. Curr Med Res Opin 30(2):185–190. doi:10.1185/03007995.2013.858617
22. Bedini JL, Wallace JF, Pardo S, Petruschke T (2015) Performance evaluation of three blood glucose monitoring systems using ISO 15197: 2013 accuracy criteria, consensus and surveillance error grid analyses, and insulin dosing error modeling in a hospital setting. J Diabetes Sci Technol 10(1):85–92. doi:10.1177/1932296815609368
23. Jendrike N, Rittmeyer D, Pleus S, Baumstark A, Haug C, Freckmann G (2015) ISO 15197:2013 accuracy evaluation of two CE-marked systems for self-monitoring of blood glucose. J Diabetes Sci Technol 9(4):934–935. doi:10.1177/1932296815582223
24. Freckmann G, Schmid C, Baumstark A, Pleus S, Link M, Haug C (2012) System accuracy evaluation of 43 blood glucose monitoring systems for self-monitoring of blood glucose according to DIN EN ISO 15197. J Diabetes Sci Technol 6(5):1060–1075. doi:10.1177/193229681200600510
25. Boettcher C, Dost A, Wudy SA, Flechtner-Mors M, Borkenstein M, Schiel R et al (2014) Accuracy of blood glucose meters for self-monitoring affects glucose control and hypoglycemia rate in children and adolescents with type 1 diabetes. Diabetes Technol Ther 17(4):275–282. doi:10.1089/dia.2014.0262
26. de Mol P, Krabbe HG, de Vries ST, Fokkert MJ, Dikkeschei BD, Rienks R et al (2010) Accuracy of handheld blood glucose meters at high altitude. PLoS ONE 5(11):1–8. doi:10.1371/journal.pone.0015485
27. Ginsberg BH (2009) Factors affecting blood glucose monitoring: sources of errors in measurement. J Diabetes Sci Technol 3(4):903–913. doi:10.1177/193229680900300438
28. Hirose T, Mita T, Fujitani Y, Kawamori R, Watada H (2011) Glucose monitoring after fruit peeling: pseudohyperglycemia when neglecting hand washing before fingertip blood sampling: wash your hands with tap water before you check blood glucose level. Diabetes Care 34(3):596–597. doi:10.2337/dc10-1705
29. Olateju T, Begley J, Flanagan D, Kerr D (2012) Effects of simulated altitude on blood glucose meter performance: implications for in-flight blood glucose monitoring. J Diabetes Sci Technol 6(4):867–874. doi:10.1177/193229681200600418
30. Farrell SP, Hains AA, Davies WH, Smith P, Parton E (2004) The impact of cognitive distortions, stress, and adherence on metabolic control in youths with type 1 diabetes. J Adolesc Health 34(03):461–467. doi:10.1016/S1054-139X(03)00215-5
31. Smalls BL, Walker RJ, Hernandez-Tejada MA, Campbell JA, Davis KS, Egede LE (2012) Associations between coping, diabetes knowledge, medication adherence and self-care behaviors in adults with type 2 diabetes. Gen Hosp Psychiatry 34(4):385–389. doi:10.1016/j.genhosppsych.2012.03.018
32. Bryden KS, Peveler RC, Stein A, Neil A, Mayou RA, Dunger DB (2001) Clinical and psychological course of diabetes from adolescence to young adulthood: a longitudinal cohort study. Diabetes Care 4(9):1536–1540. doi:10.2337/diacare.24.9.1536
33. Hains AA, Berlin KS, Davies WH, Parton EA, Alemzadeh R (2006) Attributions of adolescents with type 1 diabetes in social situations. Diabetes Care 29(4):818–822. doi:10.2337/diacare.29.04.06.dc05-1828
34. Lewin A, Heidgerken A, Geffken G, Williams L, Storch E, Gelfand K et al (2006) The relation between family factors and metabolic control: the role of diabetes adherence. J Pediatr Psychol 31(2):174–183. doi:10.1093/jpepsy/jsj004
35. Hilliard ME, Rohan JM, Carle AC, Pendley JS, Delamater A, Drotar D (2011) Fathers' involvement in preadolescents' diabetes adherence and glycemic control. J Pediatr Psychol 36(8):911–922. doi:10.1093/jpepsy/jsr020
36. Rapoff MA (2010) Issues in clinical child psychology: adherence to pediatric medical regimens, 2nd edn. Springer, New York, USA. doi:10.1007/978-1-4419-0570-3
37. Cluss PA, Epstein LH, Galvis SA, Fireman P, Friday G (1984) Effect of compliance for chronic asthmatic children. J Consult Clin Psychol 52(5):909–910
38. Branstetter-Rost AD, Berg CJ, Rapoff MA, Belmont JM (2010) Predicting children' s adherence to asthma medication regimens. J Behav Health Med 3:172–185
39. Berg C, Rapoff M, Snyder C, Belmont J (2007) The relationship of children's hope to pediatric asthma treatment adherence. J Posit Psychol 2:176–184
40. Cassel EJ (1982) The nature of suffering and the goals of medicine. N Engl J Med Mass Med Soc 306(11):639–645. doi:10.1056/NEJM198203183061104