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(71) Applicant: LUNA HEALTH, INC. [US/US]; 1815 W 13th
St Ste 5, Wilmington, Delaware 19806 (US).(72) Inventors: SJÖLUND, Per John; 11696 Sorrento Val-
ley Road, San Diego, California 92121 (US). PRYOR,

Jack David; 19 Christopher Street, Ladera Ranch, California 92694 (US). SAINT, Sean Thomas; 7809 Entrada de Luz E, San Diego, California 92127 (US). DESBOROUGH, Lane; 725 Old Farm Road, Thousand Oaks, California 91360 (US).

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(54) Title: INSULIN MANAGEMENT FOR DELIVERING INSULIN DURING A FASTING PERIOD

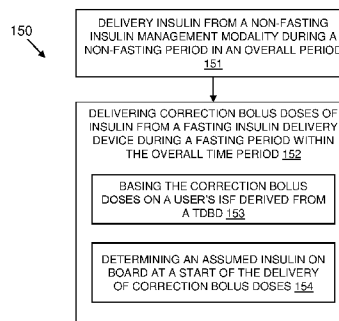
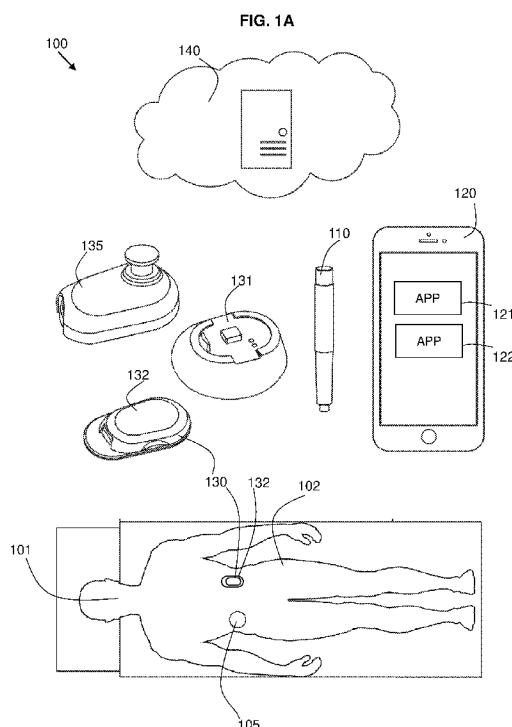


FIG. 1B

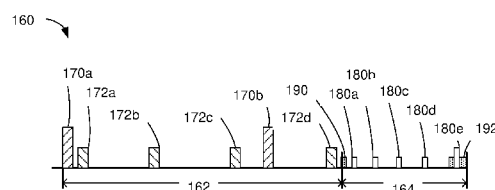


FIG. 1C

(57) Abstract: According to some embodiments, an insulin management method implemented by an insulin delivery system including an insulin delivery device (130). The method includes: determining (154, 225) an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose; and delivering (152, 233) insulin from the insulin delivery device (130) with the insulin in the form of a plurality of correction bolus doses during a fasting period in response to received blood glucose measurements, the correction bolus doses compensated for by a determined insulin on board, wherein for at least a first correction bolus dose of the plurality of correction bolus doses the determined insulin on board equals the assumed insulin on board.



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INSULIN MANAGEMENT FOR DELIVERING INSULIN DURING A FASTING PERIOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to US Provisional Patent Application Serial Number 63/332,001, filed on April 18, 2022, and entitled "INSULIN MANAGEMENT FOR DELIVERING INSULIN DURING A FASTING PERIOD", the contents of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

This disclosure relates to insulin management. In particular, the disclosure relates to insulin management for delivering insulin during a fasting period. The disclosure also relates to coordination of such insulin management with another therapy modality. The disclosure also relates to glucagon management using equivalent management systems, devices, and methods to those described for insulin.

BACKGROUND TO THE INVENTION

Numerous diabetes management methods are currently used in the form of different insulin therapies. One insulin therapy is continuous subcutaneous insulin therapy provided by continuous-use insulin pumps. Known insulin pumps provide continuous subcutaneous insulin infusion (CSII) by attachment to a user's body with a reservoir of insulin inside the pump for delivery via a cannula for subcutaneous insertion. The insulin pump has a controller that may be integrated into the pump body or provided separately that controls the delivery of insulin. Automated insulin delivery (AID) is provided by using a pump with blood glucose monitoring from a device attached to the body that takes periodic blood glucose readings.

Known insulin pumps are worn continuously day and night and therefore the insulin pumps deliver a single type of rapid-acting insulin as a combination of basal and bolus insulin. The basal insulin is the background insulin that a person needs to maintain target blood glucose and does not count insulin administered or determined to counteract blood glucose elevations caused by ingested food. Where provided by CSII, such fast-acting basal or background insulin is conventionally provided at a preset and/or default basal rate and delivered to the user in a preset and/or default basal pattern, for example, 2 units per hour delivered at a continuous rate or delivered in a series of predetermined doses that are not calculated or adjusted based on real-time glucose values. On pumps, the basal rates may be varied over time but are generally stable and represent about 50% of the total insulin needs of somebody with Type 1 diabetes. In contrast to CSII basal and/or background insulin, CSII meal bolus insulin doses are pumped to cover food eaten or to correct

a high blood glucose level. Known insulin pumps require accurate estimates of numerous user-specific variables that must be used to ensure safe and effective insulin delivery over a 24-hour cycle. However, accurate estimates can be difficult to determine and require tuning over time. Continuous-use insulin pumps suffer from high costs and patient inconvenience due to a requirement to be attached to the body continuously, day and night.

Another popular diabetes management method is provided by multiple daily injections (MDI) to provide conventional insulin therapy or flexible insulin therapy. Various regimes are known and may include bolus insulin (or meal insulin) supplied by injection of rapid-acting insulin before each meal in an amount proportional to the meal and basal insulin provided as a once or twice daily injection of a long-acting insulin. Insulin pen solutions for providing MDI, which are used by the majority of patients, typically provide lower cost and higher flexibility for patients as compared to CSII. However, the use of insulin pens, along with syringes and inhalable solutions, suffer from a requirement to be awake to use, resulting in reduced rest and/or reduced glucose control, particularly at night, when the patient would like to rest undisturbed and wake up in a healthy target glucose range.

Typically, a patient with diabetes uses a single solution for their diabetes management therapy at least in part due to the complexity of and/or risk associated with coordination of different therapies. Some risks include unrecognized insulin stacking and misinformed insulin delivery. Each available diabetes management method has a set of unique behavioral requirements, costs and potential clinical outcomes. No one solution meets the preferred behavioral, cost and clinical outcome requirements for all patients with diabetes. Patients typically follow a physician recommendation for a particular method and adapt their lifestyle to that solution.

The preceding discussion of the background to the invention is intended only to facilitate an understanding of the present invention. It should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was part of the common general knowledge in the art as at the priority date of the application.

SUMMARY OF THE INVENTION

Aspects of the present invention are defined in the appended claims. Varying aspects of the disclosure are defined in the following paragraphs and one or more combination of the optional features may be combined with the different aspects. According to an aspect of the present disclosure there is provided an insulin management method implemented by an insulin delivery system including an insulin delivery device, comprising: determining an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of a user to a target blood glucose; and delivering insulin from the insulin delivery device with the insulin in

the form of a plurality of correction bolus doses during a fasting period in response to received blood glucose measurements, the correction bolus doses compensated for by a determined insulin on board, wherein for at least a first correction bolus dose of the plurality of correction bolus doses the determined insulin on board equals the assumed insulin on board.

The insulin delivery system that implements the method may include an insulin delivery device including a controller and, optionally, one or more computing devices at which some of the method steps may be carried out. For example, one of the computing devices may be a user's mobile computing device. The insulin delivery device may be an automatic insulin delivery device attachable to a user's body for a duration of the fasting period and configured to refrain from administering basal insulin at a preset or default rate or in a preset or default pattern.

The assumed insulin on board is initially assumed to be sufficient to bring an initial blood glucose measurement into a target range and is reduced over time during the fasting period. The method may include adjusting the assumed insulin on board over time based on comparisons between to the evaluated blood glucose measurement. The determined insulin on board may include a known delivered insulin from delivered correction doses from the delivery device during the fasting period. The method may include calculating each of the plurality of correction bolus doses by comparing an evaluated blood glucose measurement to the target blood glucose to obtain a difference, adjusting the difference by a user insulin sensitivity factor to obtain a resultant dose amount, and reducing the resultant dose amount by the determined insulin on board. The method may, at the start of the delivery from the insulin delivery device, calculate the assumed external dose to correct an initial blood glucose measurement of the user to the target blood glucose. The determined insulin on board may be a combination of at least the assumed insulin on board and a known delivered insulin from the delivery device during the fasting period once insulin is delivered. The correction bolus doses are calculated based on a user's insulin sensitivity factor obtained for the user. The user's insulin sensitivity factor is derived from a total daily basal dose information used in a defined period prior to the fasting period. The correction bolus doses may be calculated based on at least one of a fixed target blood glucose for all users and a fixed insulin action time for all users. The method may limit the correction bolus doses to a defined maximum dose per correction bolus dose such that the correction bolus dose is a divided portion of a total correction bolus dose.

The evaluated blood glucose measurements may be evaluated using various different methods that may be used individually or combined. The evaluated blood glucose measurement is evaluated at least in part by smoothing the received blood glucose measurements with a low pass filter to reduce the effect of noise and/or abrupt perturbations to obtain blood glucose values. The evaluated blood glucose measurement may be evaluated at least in part by retaining a received

blood glucose measurement that is less than a rolling average of a predetermined number of prior received blood glucose measurements and retaining the rolling average for the received blood glucose measurement otherwise. The evaluated blood glucose measurement may be evaluated at least in part by projecting a downward trend of the received blood glucose measurements forward and adding the downward trend to the blood glucose measurement value used in the dose calculation. The downward trend may be determined based at least in part on a largest negative slope between any received blood glucose measurement within a predetermined timeframe and a reference blood glucose measurement. The evaluated blood glucose measurement may be evaluated at least in part by fitting received blood glucose measurements within a predetermined timeframe to a trend having an average slope (for example, a median slope) selected from a plurality of regression fit slopes for different rolling subsets of received blood glucose measurements within the predetermined timeframe. The evaluated blood glucose measurement may be evaluated at least in part by filtering the received blood glucose measurements, the filtering comprising: imposing a progressively increasing limit on how much each next received blood glucose measurement can increase compared to the previous received blood glucose measurement for increasing received blood glucose measurements; and amplifying how much each next received blood glucose measurement decreases compared to the previous received blood glucose measurement for decreasing received blood glucose measurements.

According to an aspect of the present disclosure there is provided an insulin management method implemented by a controller of an insulin delivery device for delivering insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device, comprising: determining a user insulin sensitivity factor; receiving blood glucose measurements; evaluating the blood glucose measurements to obtain evaluated blood glucose values; determining an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose; calculating periodic correction bolus doses by comparing an evaluated blood glucose value to a target blood glucose to obtain a difference, the difference adjusted by the user insulin sensitivity factor to obtain a resultant dose amount, and the resultant dose amount compensated by a determined insulin on board, wherein: correction bolus doses in an initial period are calculated using the determined insulin on board set equal to the assumed insulin on board; and delivering at least a portion of a calculated correction dose at periodic time intervals. The controller may be provided on-board the delivery device or may be formed of components distributed across other computing devices that carry out some of the controller processing steps. The additional method features listed in relation to the above aspect may also apply individually or in combination to this aspect.

The method may include dividing the correction dose into delivery portions with a maximum delivery rate for a maximum amount of insulin to be delivered over a given time period. The method may include determining an initial user insulin sensitivity factor for the fasting period based on a received total daily basal dose information. The method may include adjusting the initial user insulin sensitivity factor by a sensitivity safety factor configured to bias the calculating periodic correction bolus doses to less insulin dosage. Adjusting the target blood glucose by a target safety factor may be based at least in part on a difference between a received blood glucose measurement and the target blood glucose. Adjusting the calculated correction bolus dose by an overall safety factor may be configured to limit the calculated bolus dose to a maximum delivery rate for insulin to be delivered over a time period between delivery of correction bolus doses. The target blood glucose may be time varying to decrease over time during the fasting period and a rate of decrease over time of the target blood glucose is determined based on an assumption that blood glucose levels are being lowered by existing externally administered insulin administered prior to the fasting period. The user insulin sensitivity factor may be initially set at a predetermined value and adjusted over time based at least in part on a difference between received blood glucose measurements and expected blood glucose. Evaluating the blood glucose measurements may include filtering for increasing blood glucose values and not filtering for decreasing blood glucose values. Evaluating the blood glucose measurements may include adjusting for a long term downward trend over a period of hours in the fasting period. Delivering at least a portion of the correction doses may include delivering a first zero dose.

According to another aspect of the present disclosure there is provided an insulin management system of an insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period, the system comprising: a delivery component of the insulin delivery device configured to deliver insulin in the form of a plurality of correction bolus doses in response to received blood glucose measurements, the correction bolus doses compensated for by a determined insulin on board, wherein for at least a first correction bolus dose of the plurality of correction bolus doses the determined insulin on board equals an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose.

The delivery component may include: an insulin sensitivity factor receiving component configured to determine a user insulin sensitivity factor; a blood glucose measurement receiving component configured to periodically receive blood glucose measurements; a blood glucose measurement evaluating component configured to evaluate the blood glucose measurements; a correction dose calculating component configured to calculate the periodic correction bolus; and wherein, the delivery component delivers at least a portion of a calculated correction dose at time intervals.

The insulin sensitivity factor receiving component may be configured to derive an initial insulin sensitivity factor from a total daily basal dose information received from a non-fasting insulin management modality in a defined period prior to the fasting period for use in determining the correction bolus doses. The delivery component may include an insulin on board determining component including an assumed insulin on board component configured to calculate an initial assumed correction dose to correct an initial blood glucose measurement of the user to a target blood glucose. The insulin on board determining component may also include a device insulin on board component and the correction bolus doses of the fasting period are calculated based on assumed insulin on board and known delivered insulin from the delivery device. The delivery component may include an activation component for detecting activation of the delivery device to commence delivery of insulin from the fasting insulin delivery device. The correction dose calculating component may be configured to determine the correction bolus doses for the fasting period at each blood glucose measurement timepoint to determine if insulin is required to bring the user to a target blood glucose.

The measurement evaluating component may be configured to perform at least one of: smoothing the received blood glucose measurements with a low pass filter to reduce the effect of noise and/or abrupt perturbations to obtain blood glucose values; retaining a received blood glucose measurement that is less than a rolling average of a predetermined number of prior received blood glucose measurements and retaining the rolling average for the received blood glucose measurement if the received blood glucose is not less than the rolling average; projecting a downward trend of the received blood glucose measurements forward and adding the downward trend to the blood glucose measurement value used in the dose calculation; filtering the received blood glucose measurements, the filtering comprising imposing a progressively increasing limit on how much each next received blood glucose measurement can increase compared to the previous received blood glucose measurement for increasing received blood glucose measurements, and amplifying how much each next received blood glucose measurement decreases compared to the previous received blood glucose measurement for decreasing received blood glucose measurements; and fitting received blood glucose measurements within a predetermined timeframe to a trend having a median slope selected from a plurality of regression fit slopes for different rolling subsets of received blood glucose measurements within the predetermined timeframe.

The delivery component may include a correction dose limiting component configured to limit the correction bolus doses for the fasting period to a defined maximum dose given at any time point to minimize sudden corrections. The correction dose limiting component may be configured to limit each of the correction bolus doses for the fasting period to at least a minimum dose deliverable by the delivery device hardware. The delivery component may include a safety factor

component configured to provide safety factors to parameters on which the dose correction is based. The delivery component may include an end-procedure component configured to coordinate an end bolus delivery at the end of the fasting period. The delivery component includes a processor and a memory configured to provide non-transitory, computer-readable program instructions to the processor to execute functions of the components.

The insulin management system may include a mobile user computing device comprising: a processor and a memory configured to provide non-transitory, computer-readable program instructions to the processor to execute functions of components: a basal insulin input component for requesting a value from a user of a total daily basal dose information used in a defined period prior to the fasting period; and a controller pairing component for pairing the mobile user computing device to a controller of the delivery device.

According to an aspect of the present disclosure there is provided an automatic insulin delivery device attachable to a user's body for a duration of a fasting period, the device comprising: a durable portion including a delivery component configured to control a delivery of insulin in the form of a plurality of correction bolus doses in response to received blood glucose measurements, at least the first correction bolus dose of the plurality of correction bolus doses determined based on a determined insulin on board equal to an assumed insulin on board that is determined based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose; and a disposable portion including a reservoir configured to contain insulin and configured to automatically deliver the correction bolus doses to the user. The reservoir may be configured to be fillable from a non-fasting insulin injection device used during a non-fasting period.

According to an aspect of the present disclosure there is provided a computer-implemented method for managing delivery of insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period, wherein the method is carried out by a computing application provided at a mobile user computing device, the method comprising: requesting a value from a user of a total daily basal dose information used in a defined period prior to the fasting period; pairing the mobile user computing device to a controller of the delivery device, the controller configured to control a delivery of insulin in the form of a plurality of correction bolus doses in response to received blood glucose measurements, the correction bolus doses compensated for by a determined insulin on board, wherein for at least a first correction bolus dose of the plurality of bolus doses the determined insulin on board is equal to an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose; and transmitting and receiving information to and from the controller of the delivery device during the fasting period.

Requesting a value from a user of a total daily basal dose information may include requesting a usual number of units of basal insulin received from a non-fasting form of insulin therapy. The method may include pairing the mobile user computing device to a blood glucose monitor to transfer blood glucose measurements to the delivery device. The method may provide a display of a session history of information relating to the fasting period. The method may include providing user training in use of a delivery device. The method may include coordinating a fast-ending procedure for the user including dividing a fast-ending meal bolus into a first portion equal to a remaining insulin in the delivery device at the end of the fasting period and a second portion to be delivered to the user utilizing a delivery method other than the delivery device in a non-fasting period immediately following the fasting period.

According to an aspect of the present disclosure there is provided an insulin management method implemented by an insulin delivery system including an insulin delivery device, comprising: detecting a starting activity associated with preparation of use of the insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period within an overall time period; and initiating automated delivery of insulin in the form correction bolus doses in response to periodically received blood glucose measurements during the fasting period. The insulin delivery system may be self-contained within the insulin delivery device with a controller carrying out the method steps. Alternatively, the insulin delivery system may include one or more computing systems that carry out one or more of the method steps remotely.

The method may include detecting an ending activity associated with ending the use of the insulin delivery device; and terminating automated delivery of the insulin correction bolus doses. The starting activity may have a primary function other than initiating automated delivery of insulin from the insulin delivery device, thereby, being simultaneously reused as an indication to initiate automated delivery of insulin from the insulin delivery device. The starting activity may comprise one or more of: arrival of a pre-set time of the day; removal of the insulin delivery device from a power charger; and attachment of a disposable insulin dispensing unit to the insulin delivery device. The starting activity may comprise one or more of: attachment of the insulin delivery device to the user; detachment of an applicator of the insulin delivery device from the insulin delivery device; and a verbal command or selection by the user indicating a desire to initiate automated delivery of insulin. The starting activity may comprise at least one of: a proximity to or pairing of a controller of the insulin delivery device to a user computing device on which a user application associated with the insulin delivery device is installed; a proximity to or pairing of the controller of the insulin delivery device to a smart insulin pen; a proximity to or pairing of the controller of the insulin delivery device to a blood glucose monitor; receiving a blood glucose

monitor measurement; a fill level of an insulin reservoir of a disposable insulin dispensing unit indicative of a sufficiently filled insulin reservoir for initiating the automated delivery of insulin; and a movement of a plunger of an insulin reservoir of a disposable insulin dispensing unit indicative of a filling of the insulin reservoir. The method may include receiving from a paired user computing device a total daily basal dose information as received from a non-fasting insulin management modality in a defined period prior to the fasting period for use in determining the correction bolus doses. Initiating automated delivery of insulin may include priming the delivery device to be ready to deliver the insulin.

According to an aspect of the present disclosure there is provided an insulin management system of an insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period within an overall time period, the system comprising: an activation component configured to detect a starting activity associated with preparation of use of the insulin delivery device; and a delivery component configured to initiate automated delivery of insulin in the form of correction bolus doses in response to periodically received blood glucose measurements during the fasting period. The system may include an end detecting component configured to detect an ending activity associated with ending the use of the insulin delivery device.

The activation component may be configured to detect, as the starting activity, one or more of: arrival of a pre-set time of the day as the starting activity; removal of the insulin delivery device from a power charger; and attachment of a disposable insulin dispensing unit to the insulin delivery device. The activation component may be configured to detect, as the starting activity, one or more of: attachment of the insulin delivery device to the user; detachment of an applicator of the insulin delivery device from the insulin delivery device; and a verbal command or selection by the user indicating a desire to initiate automated delivery of insulin. The activation component may be configured to detect, as the starting activity, one or more of: a proximity to or pairing of a controller of the insulin delivery device to a user computing device on which a user application associated with the insulin delivery device is installed; a proximity to or pairing of the controller of the insulin delivery device to a smart insulin pen; a proximity to or pairing of the controller of the insulin delivery device to a blood glucose monitor; receiving a blood glucose monitor measurement; a fill level of an insulin reservoir of a disposable insulin dispensing unit indicative of a sufficiently filled insulin reservoir for initiating the automated delivery of insulin; and a movement of a plunger of an insulin reservoir of a disposable insulin dispensing unit indicative of a filling of the insulin reservoir. The activation component may be configured to detect receiving, from the paired user computing device, a total daily basal dose information as received from a non-fasting insulin management modality in a defined period prior to the fasting period for use in determining the correction bolus doses.

The delivery component may be configured to prime the delivery device to be ready to deliver the insulin. The delivery component may comprise a processor and a memory configured to provide non-transitory, computer-readable program instructions to the processor to execute functions of the components.

The system may further include a mobile user computing device comprising: a processor and a memory configured to provide non-transitory, computer-readable program instructions to the processor to execute functions of components; a basal insulin input component configured to request a value from a user of a total daily basal dose information used in a defined period prior to the fasting period; and a controller pairing component configured to pair the mobile user computing device to a controller of the delivery device.

According to an aspect of the present disclosure there is provided an automatic insulin delivery device attachable to a user's body for a duration of a fasting period, the device comprising: a durable portion including a delivery component configured to control a delivery of insulin in the form of correction bolus doses in response to received blood glucose measurements, the delivery component comprising: an activation component configured to detect a starting activity associated with preparation of use of the insulin delivery device; and a delivery component configured to initiate automated delivery of insulin in the form of correction bolus doses in response to periodically received blood glucose measurements during the fasting period; and a disposable portion comprising a reservoir configured to contain insulin and configured to automatically deliver the correction bolus doses to the user. The reservoir may be configured to be fillable from a non-fasting insulin injection device used during a non-fasting period preceding the fasting period.

According to an aspect of the present disclosure there is provided computer-implemented method for managing delivery of insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period, wherein the method is carried out by a computing application provided at a mobile user computing device, the method comprising: requesting from a user a value of a total daily basal dose information used in a defined period prior to the fasting period; pairing the mobile user computing device to a controller of the delivery device, the controller detecting a starting activity associated with preparation of use of the insulin delivery device, thereby, initiating automated delivery of insulin in the form correction bolus doses in response to periodically received blood glucose measurements during the fasting period; and transmitting and receiving information to and from the controller of the delivery device during the fasting period. The value from the user of the total daily basal dose information may include a usual number of units of basal insulin received from a non-fasting form of insulin therapy.

The method may include pairing the mobile user computing device to a blood glucose monitor, thereby, allowing transfer of blood glucose measurements to the delivery device via the mobile user computing device. The method may include providing a display of a session history of information relating to a fasting period to the user. The method may include providing user training in use of a delivery device to the user. The method may include coordinating a fast-ending procedure for the user including dividing a fast-ending meal bolus into a first portion equal to a remaining insulin in the delivery device at the end of the fasting period and a second portion to be delivered to the user utilizing a delivery method other than the delivery device in a non-fasting period immediately following the fasting period.

According to an aspect of the present disclosure there is provided an insulin management method of use of an insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period within an overall time period, the method comprising: carrying out a starting activity associated with preparation of use of the insulin delivery device ; and receiving automated delivery of insulin in the form correction bolus doses in response to periodically received blood glucose measurements during the fasting period. The method may provide at least one of an insulin sensitivity factor and total daily basal dose information used by the user in a defined period prior to the fasting period to the insulin delivery device.

The method may include carrying out an ending activity associated with ending the user of the insulin delivery device. Carrying out the starting activity may comprise one or more of: removal of the insulin delivery device from a power charger; and attachment of a disposable insulin dispensing unit to the insulin delivery device. Carrying out the starting activity comprises one or more of: attachment of the insulin delivery device to the user; detachment of an applicator of the insulin delivery device from the insulin delivery device; and a verbal command or selection by the user indicating a desire to initiate automated delivery of insulin. Carrying out the starting activity comprises at least one of: pairing a controller of the insulin delivery device to a user computing device on which a user application associated with the insulin delivery device is installed; pairing the controller of the insulin delivery device to a smart insulin pen; filling an insulin reservoir of a disposable insulin dispensing unit; causing movement of a plunger of the insulin reservoir indicative of a filling of the insulin reservoir.

According to an aspect of the present disclosure there is provided an insulin management method, comprising: providing an insulin delivery device, wherein the insulin delivery device is in the form of an automatic insulin delivery device attachable to a user's body for the duration of a fasting period; and delivering insulin from the insulin delivery device during the fasting period within an overall time period in the form of correction bolus doses of insulin in response to received

blood glucose measurements, wherein the insulin delivery device refrains from administering basal insulin at a preset or default rate or in a preset or default pattern, wherein insulin is received by the user from a non-fasting insulin management modality during a non-fasting period within the overall time period and the non-fasting insulin management modality provides at least one of a basal dose of insulin and bolus doses of insulin. A single non-fasting period and a single fasting period may be provided in the overall time period and wherein the single fasting period is the major sleep portion of a user's regular daily routine.

The method may include calculating the correction bolus doses by comparing an evaluated blood glucose measurement to a target blood glucose to obtain a difference, the difference adjusted by a user insulin sensitivity factor to obtain a resultant dose amount and the resultant dose amount compensated by a determined insulin on board. The user's insulin sensitivity factor may be derived from a total daily basal dose information received from the non-fasting insulin management modality in a defined period prior to the fasting period. The method may include, for calculating at least the first correction bolus dose, the determined insulin on board being equal to an assumed insulin on board calculated as an assumed external dose to correct an initial blood glucose value of the user to a target blood glucose. The determined insulin on board may comprise the assumed insulin on board and a known delivered insulin from the delivery device. The target blood glucose may be fixed for all users. Delivering the insulin from the insulin delivery device during the fasting period may be commenced based on detection of activation of the delivery device by the user. The correction bolus doses for the fasting period may be calculated at each blood glucose measurement timepoint to determine the timing and amount of insulin required to bring the user to the target blood glucose.

The method may comprise providing coordination between the non-fasting insulin management therapy and the delivery device to the user. The coordination may comprise providing one or more recommendations to a user relating to the non-fasting insulin management therapy and/or the delivery device. The coordination may comprise providing one or more predictions to a user relating to hypothetical use of the non-fasting insulin management therapy and/or the delivery device. The one or more recommendations comprise at least one of: a recommendation for the user to utilize the delivery device for a recommended timeframe at night; and a recommendation for the user to adjust daily basal doses of insulin from a current value to a different value. The one or more predictions comprise one or more of: a prediction of waking blood glucose levels for the user if the user utilizes the delivery device for the recommended timeframe at night; a prediction of waking blood glucose levels for the user if the user adjusts daily basal doses of insulin from a current value to the different value; and a prediction of waking blood glucose levels for the user if the user does not utilize the delivery device for an entire night.

The coordination may comprise: coordinating a fast-ending procedure for the user, wherein coordinating the fast-ending procedure comprising: receiving information relating to a fast-breaking meal that requires a meal bolus; dividing a fast-ending meal bolus into a first portion equal to a remaining insulin in the delivery device at the end of the fasting period and a second portion to be delivered to the user utilizing the non-fasting insulin management modality in a non-fasting period immediately following the fasting period; and providing the user with instructions to deliver the second portion of the fast-ending meal bolus dose from the non-fasting insulin management modality.

According to an aspect of the present disclosure there is provided an insulin management system of an insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period within an overall time period, the system comprising: a delivery component configured to deliver insulin from the insulin delivery device during the fasting period in the form of correction bolus doses of insulin in response to received blood glucose measurements, wherein the delivery component refrains from administering basal insulin at a preset or default rate or in a preset or default pattern, wherein insulin is received from a non-fasting insulin management modality during a non-fasting period within the overall time period and the non-fasting insulin management modality provides at least one of a basal dose of insulin and bolus doses of insulin.

The delivery component may be configured to calculate the correction bolus doses by comparing an evaluated blood glucose measurement to a target blood glucose to obtain a difference, the difference adjusted by a user insulin sensitivity factor to obtain a resultant dose amount, and the resultant dose amount compensated by a determined insulin on board. The delivery component may include an initializing component configured to, at the start of the delivery from the fasting insulin delivery device, determine an assumed insulin on board as an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose.

The system may also include a mobile user computing device comprising: a processor and a memory configured to provide non-transitory, computer-readable program instructions to the processor to execute functions of components: a basal insulin input component for requesting a value from a user of a total daily basal dose information used in a defined period prior to the fasting period; a controller pairing component for pairing the mobile user computing device to a controller of the delivery device.

According to an aspect of the present disclosure there is provided an automatic insulin delivery device attachable to a user's body for a duration of a fasting period, the device comprising: a durable portion including a delivery component configured to control a delivery of insulin in the

form of a plurality of correction bolus doses of insulin in response to received blood glucose measurements and refraining from administering basal insulin at a preset or default rate or in a preset or default pattern; and a disposable portion including a reservoir configured to contain insulin and configured to automatically deliver the correction bolus doses to the user under control of the delivery component.

According to an aspect of the present disclosure there is provided computer-implemented method for managing delivery of insulin when using a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period, wherein the method is carried out by a computing application provided at a mobile user computing device, the method comprising: receiving information relating to a non-fasting insulin management therapy used during a non-fasting period in an overall period; receiving information relating to the delivery device used during a fasting period in the overall period; and providing coordination between the non-fasting insulin management therapy and the delivery device. The method may include providing one or more recommendations to a user relating to the non-fasting insulin management therapy and/or the delivery device. The method may include providing one or more predictions to a user relating to hypothetical use of the non-fasting insulin management therapy and/or the delivery device.

According to an aspect of the present disclosure there is provided insulin management method of use comprising: receiving insulin from a non-fasting insulin management modality during a non-fasting period within an overall time period, wherein the non-fasting insulin management modality provides required doses of insulin during the non-fasting period; receiving insulin from a fasting insulin delivery device during a fasting period within the overall time period, wherein the fasting insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period and is configured to deliver correction bolus doses of insulin in response to received blood glucose measurements and refrains from administering basal insulin at a preset or default rate or in a preset or default pattern; receiving, from a coordinating computing device, at least one of: a recommendation to a user relating to the non-fasting insulin management therapy and/or the delivery device; and a prediction to a user relating to hypothetical use of the non-fasting insulin management therapy and/or the delivery device.

A medicament management system of a medicament delivery device in the form of an automatic medicament delivery device for a medicament affecting blood glucose levels and attachable to a user's body for a duration of a fasting period or an activity period within an overall time period, the system comprising: a delivery component configured to deliver correction doses of the medicament from the delivery device during the fasting period or an activity period in response to received blood glucose measurements.

An automatic medicament delivery device for a medicament affecting blood glucose levels and attachable to a user's body for a duration of a fasting period or activity period, the device comprising: a durable portion including a delivery component configured to control a delivery of the medicament in the form of a plurality of correction doses of the medicament in response to received blood glucose measurements; and a disposable portion including a reservoir configured to contain the medicament and configured to automatically deliver the correction doses to the user under control of the delivery component.

In one embodiment, the medicament may be glucagon. The features of the aspects of the disclosure disclosed in relation to the insulin delivery device may be provided, where appropriate, in the glucagon or other blood glucose affecting medicament embodiments. In particular, the correction doses may be provided in response to blood glucose targets with appropriate safety factors.

According to an aspect of the present disclosure there is provided an insulin management method comprising: delivering insulin from a non-fasting insulin management modality during a non-fasting period within an overall time period, wherein the non-fasting insulin management modality provides basal doses of insulin and bolus doses of insulin; delivering insulin from a fasting insulin delivery device during a fasting period within the overall time period, wherein the fasting insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period, and wherein the fasting insulin delivery device delivers correction bolus doses in response to received blood glucose measurements and refrains from administering background basal doses.

A single non-fasting period and a single fasting period together may be provided in the overall time period and wherein the single fasting period may be the major sleep portion of a user's regular daily routine. The correction bolus doses of a fasting period may be based on a user's insulin sensitivity factor derived from a total daily basal dose information received from the non-fasting insulin management modality in a defined period prior to the fasting period. The total daily basal dose information may be an average total number of basal dose units given in an overall time period. At the start of the delivery from the fasting insulin delivery device, the method may include using an assumed insulin on board in the correction bolus doses based on calculating an initial hypothetical correction bolus dose to correct an initial blood glucose measurement of the user to a target blood glucose and may apply the hypothetical dose as an assumed insulin on board. The correction bolus doses of a fasting period may be based on assumed insulin on board and a known delivered insulin from the delivery device. The correction bolus doses for a fasting period may be based on a fixed target blood glucose and insulin action time for all users. Receiving insulin from a fasting insulin delivery device during a fasting period may be commenced

on detection of activation of the delivery device by the user. The correction bolus doses for a fasting period may be calculated by a dose calculator at each blood glucose measurement timepoint to determine when and how much insulin is required to bring the user to a target blood glucose. The dose calculator may compare a blood glucose value to a target blood glucose to obtain a difference that is adjusted by a user insulin sensitivity factor, wherein a resultant dose amount is compensated by a determined insulin on board. The received blood glucose measurements may be smoothed with a low pass filter to reduce the effect of noise and/or abrupt perturbations to obtain blood glucose values. When the received blood glucose measurements are trending downward over time, the downward trend may be projected forward and added to the blood glucose value used in the dose calculator. The correction bolus doses for a fasting period may be limited to a defined maximum dose given at any time point to minimize sudden corrections. The correction bolus doses for a fasting period may be limited based on the delivery device hardware. The correction bolus doses for a fasting period may be divided into delivery portions with a maximum delivery rate for a maximum amount of insulin to be delivered over a given time period.

According to an aspect of the present disclosure there is provided an insulin management method of an insulin delivery device comprising: delivering insulin in the form of correction bolus doses in response to received blood glucose measurements and refraining from administering background basal doses, wherein the insulin is delivered from the insulin delivery device designed for delivery during a fasting period within an overall time period, and wherein the insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period. According to an aspect of the present disclosure there is provided an insulin management method of an insulin delivery device comprising: delivering insulin in the form of correction bolus doses in response to received blood glucose measurements including an initial period of correction bolus doses based on an assumed insulin on board based on an initial hypothetical correction bolus dose calculated to correct an initial blood glucose measurement of the user to a target blood glucose, wherein the insulin is delivered from the insulin delivery device designed for delivery during a fasting period within an overall time period, and wherein the insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period.

According to an aspect of the present disclosure there is provided an insulin management method of an insulin delivery device comprising: delivering insulin in the form of correction bolus doses in response to received blood glucose measurements and based on a user's insulin sensitivity factor based on a total daily basal dose delivered prior to use of the delivery device; wherein the insulin is delivered from the insulin delivery device designed for delivery during a fasting period within an overall time period, and wherein the insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period.

According to an aspect of the present disclosure there is provided an insulin management method of an insulin delivery device comprising: detecting a starting activity associated with preparation of use of an insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period within an overall time period; initiating automated delivery of insulin in the form correction bolus doses in response to periodically received blood glucose measurements during the fasting period; and detecting an ending activity associated with ending the use of the insulin delivery device. Detecting may include detecting one or more physical activities carried out by the user in relation to the delivery device. Detecting may include detecting physical changes of the delivery device. Initiating may include priming the delivery device to be ready to deliver the insulin.

According to an aspect of the present disclosure there is provided an insulin management method for delivering insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device, comprising: determining an initial user insulin sensitivity factor for the fasting period; periodically receiving blood glucose measurements; evaluating the blood glucose measurements; calculating periodic correction doses by comparing an evaluated blood glucose measurement to a target blood glucose with a difference adjusted by the user insulin sensitivity factor and a resultant dose amount compensated by a determined insulin on board; and delivering at least a portion of a calculated correction dose at time intervals.

According to an aspect of the present disclosure there is provided an insulin management system associated with an insulin delivery device comprising: a delivery component for delivering insulin in the form correction bolus doses in response to received blood glucose measurements and refraining from administering background basal doses, wherein the insulin is delivered from the insulin delivery device designed for delivery during a fasting period within an overall time period, and wherein the insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period.

According to an aspect of the present disclosure there is provided an insulin management system associated with an insulin delivery device comprising: a delivery component for delivering insulin in the form of correction bolus doses in response to received blood glucose measurements including an initial period of correction bolus doses based on an assumed insulin on board based on an initial hypothetical correction bolus dose calculated to correct an initial blood glucose measurement of the user to a target blood glucose, wherein the insulin is delivered from the insulin delivery device designed for delivery during a fasting period within an overall time period, and wherein the insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period.

According to an aspect of the present invention there is provided an insulin management system associated with an insulin delivery device comprising: a delivery component for delivering insulin in the form of correction bolus doses in response to received blood glucose measurements and based on a user's insulin sensitivity factor based on a total daily basal dose delivered prior to use of the delivery device; wherein the insulin is delivered from the insulin delivery device designed for delivery during a fasting period within an overall time period, and wherein the insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period.

According to an aspect of the present invention there is provided an insulin management system associated with an insulin delivery device comprising: an activation component for detecting a starting activity associated with preparation of use of an insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period within an overall time period, a delivery component for initiating automated delivery of insulin in the form of correction bolus doses in response to periodically received blood glucose measurements during the fasting period; and an end detecting component for detecting an ending activity associated with ending the use of the insulin delivery device.

According to an aspect of the present invention there is provided a system for delivering insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period comprising: a processor and a memory configured to provide computer program instructions to the processor to execute functions of components: an insulin on board determining component for determining an initial user insulin sensitivity factor for the fasting period; a blood glucose measurement receiving component for periodically receiving blood glucose measurements; a blood glucose measurement evaluating component for evaluating the blood glucose measurements; a correction dose calculating component for calculating periodic correction doses by comparing an evaluated blood glucose measurement to a target blood glucose with a difference adjusted by the user insulin sensitivity factor and a resultant dose amount compensated by a determined insulin on board; and a delivery component for delivering at least a portion of a calculated correction dose at time intervals.

According to an aspect of the present invention there is provided a computer program product for delivering insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period, the computer program product comprising a computer-readable medium having stored computer-readable program code for performing the steps of: determining an initial user insulin sensitivity factor for the fasting period; periodically receiving blood glucose measurements; evaluating the blood glucose measurements;

calculating periodic correction doses by comparing an evaluated blood glucose measurement to a target blood glucose with a difference adjusted by the user insulin sensitivity factor and a resultant dose amount compensated by a determined insulin on board; and delivering at least a portion of a calculated correction dose at time intervals.

According to an aspect of the present invention there is provided an insulin management method of use comprising: receiving insulin from a non-fasting insulin management modality during a non-fasting period within an overall time period, wherein the non-fasting insulin management modality provides basal doses of insulin and bolus doses of insulin; receiving insulin from a fasting insulin delivery device during a fasting period within the 24 hour time period, wherein the fasting insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period, and wherein the fasting insulin delivery device delivers correction bolus doses in response to received blood glucose measurements and refrains from administering background basal doses.

According to an aspect of the present invention there is provided an insulin management method of use comprising: carrying out a starting activity associated with preparation of use of an insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period within an overall time period; receiving automated delivery of insulin in the form correction bolus doses in response to periodically received blood glucose measurements during the fasting period; and carrying out an ending activity associated with ending the user of the insulin delivery device.

According to an aspect of the present invention there is provided an insulin management method of use of a wearable automated insulin delivery device designed for delivery during a fasting period for delivering insulin, comprising: applying the delivery device to a user's body prior to the fasting period; providing insulin sensitivity information at least for a first use by a user of the delivery device wherein the delivery device includes a durable portion for repeated use during multiple fasting periods; and receiving at least a portion of a correction dose by based on a comparison of an evaluated blood glucose measurement to a target blood glucose with a difference adjusted by the user insulin sensitivity factor and a resultant dose amount compensated by a determined insulin on board.

The method may include filling the delivery device with insulin from a multiple daily injection therapy device. The method may include receiving a fast-ending dose to accommodate a fast-ending meal. The method may not allow the user to provide to the delivery device information relating to any of the following parameters: an amount of insulin to be delivered; a duration of insulin action; a target blood glucose; a basal rate; an IOB; and an insulin to carbohydrate ratio.

Applying the delivery device to a user's body prior to the fasting period may include using a push applicator configured to attach to an upper portion of the delivery device to allow the delivery device to be removed from a base, applied to a user's body, and a push force to be exerted by the user via the applicator to adhere the delivery device to the user's body.

According to an aspect of the present invention there is provided an automatic insulin delivery device apparatus, comprising: a delivery device attachable to a user's body including a controller for delivering insulin from a reservoir during a fasting period; and an applicator configured to hold the delivery device when applying to a user's body prior to the fasting period including a force exerting mechanism for activation by a user to release the applicator and force the delivery device onto the user's body. The delivery device may be formed of a durable portion including the controller and a disposable portion including a reservoir and a cannular. The apparatus may include a coupler for filling the delivery device from a non-fasting insulin therapy source. The apparatus may include a charging station for charging at least a portion of the delivery device when not in use.

According to an aspect of the present invention there is provided an automatic insulin delivery device apparatus provided as a kit, comprising: a durable portion of a delivery device including the controller; multiple disposable portions of the delivery device, each including a reservoir and a removable coupler for filling the reservoir; and an applicator configured to hold the delivery device when applying to a user's body including a force exerting mechanism for activation by a user to release the applicator and force the delivery device onto the user's body. The apparatus may include a charging station for charging at least a portion of the delivery device when not in use.

According to an aspect of the present invention there is provided an automatic insulin delivery device attachable to a user's body, comprising: a controller for delivering insulin from a reservoir during a fasting period, wherein the controller delivers correction bolus doses during a fasting period in response to periodically received blood glucose measurements and refrains from administering background basal doses. The reservoir may be configured to be fillable from a non-fasting insulin injection device used during a non-fasting period.

According to an aspect of the present invention there is provided a computer-implemented method for managing delivery of insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period, wherein the method is carried out by a computing application provided at a mobile user computing device, the method comprising: requesting a value from a user of a total daily basal dose information used in a defined period prior to the fasting period; pairing the mobile user computing device to a controller of the

delivery device; and transmitting and receiving information to and from the controller of the delivery device during the fasting period.

Requesting a value from a user of a total daily basal dose information may include a usual number of units of basal insulin received from a non-fasting form of insulin therapy. The method may include pairing the mobile user computing device to a blood glucose monitor to transfer blood glucose measurements to the delivery device. The method may provide a display of a session history of information relating to a fasting period. The method may include providing user training in use of a delivery device. The method may include coordinating a fast-ending procedure for the user including dividing a fast-ending meal bolus to use a remaining insulin in the delivery device at the end of the fasting period.

According to an aspect of the present invention there is provided a system for managing delivery of insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period wherein the system includes a mobile user computing device comprising: a processor and a memory configured to provide computer program instructions to the processor to execute functions of components: a basal insulin input component for requesting a value from a user of a total daily basal dose information used in a defined period prior to the fasting period; a controller pairing component for pairing the mobile user computing device to a controller of the delivery device; and an information component for transmitting and receiving information to and from the controller of the delivery device during the fasting period.

According to an aspect of the present invention there is provided a computer program product for managing delivery of insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period, the computer program product comprising a computer-readable medium having stored computer-readable program code for performing the steps of: requesting a value from a user of a total daily basal dose information used in a defined period prior to the fasting period; pairing the mobile user computing device to a controller of the delivery device; and transmitting and receiving information to and from the controller of the delivery device during the fasting period.

According to an aspect of the present invention there is provided a computer-implemented method for managing delivery of insulin when using a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period, wherein the method is carried out by a computing application provided at a mobile user computing device, the method comprising: receiving information relating to a non-fasting insulin management therapy used during a non-fasting period in an overall period; receiving information relating to the delivery device used during a fasting period in the overall period; and providing coordination between the non-fasting insulin

management therapy and the delivery device.

The method may include providing recommendations to a user relating to the non-fasting insulin management therapy and/or the delivery device. The method may include providing predictions to a user relating to hypothetical use of the non-fasting insulin management therapy and/or the delivery device. The method may include coordinating a fast-ending procedure for the user including dividing a fast-ending meal bolus to use a remaining insulin in the delivery device at the end of the fasting period.

According to an aspect of the present invention there is provided a system for managing delivery of insulin when using a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period wherein the system includes a mobile user computing device comprising: a processor and a memory configured to provide computer program instructions to the processor to execute functions of components: a non-fasting therapy component for receiving information relating to a non-fasting insulin management therapy used during a non-fasting period in an overall period; a delivery device therapy component for receiving information relating to the delivery device used during a fasting period in the overall period; and a coordination component for providing coordination between the non-fasting insulin management therapy and the delivery device.

According to an aspect of the present invention there is provided a computer program product for managing delivery of insulin when using a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period, the computer program product comprising a computer-readable medium having stored computer-readable program code for performing the steps of: receiving information relating to a non-fasting insulin management therapy used during a non-fasting period in an overall period; receiving information relating to the delivery device used during a fasting period in the overall period; and providing coordination between the non-fasting insulin management therapy and the delivery device.

According to an aspect of the present invention there is provided a method for adjunctive use of a first diabetes management modality with a second diabetes management modality, wherein the first and second modalities are designed for intermittent use by a patient during a 24 hour time period, the method comprising: detecting activity associated with preparation of a first diabetes management modality configured for subcutaneous infusion of insulin; initiating automated insulin delivery of the first diabetes management modality responsive to the detected activity, wherein the amount of automated insulin delivery is informed by a sensitivity factor for the patient; repeatedly evaluating the automated insulin delivery over a time period based on the evaluation, wherein the time period starts when automated insulin delivery is initiated responsive to the

detected activity, and wherein the time period ends when one or more of the following occur: an end to an intended fasting period is identified; removal of the wearable insulin reservoir from the body is detected; and/or a predetermined time period of less than about 24 hours has completed.

According to an aspect of the present invention there is provided a method for adjunctive use of a first diabetes management modality with a second diabetes management modality, wherein the first and second modalities are designed for intermittent use by a patient during a 24 hour time period, the method comprising: filling with insulin a first diabetes management modality configured for continuous wear during a time period; applying the first diabetes management modality to a patient's body at the beginning of the time period of intended fasting; and removing the first diabetes management modality from the body at the end of the time period of intended fasting, wherein during the time period of intended fasting usage, the patient is not required to interact with the first modality for correction bolus to be administered.

According to an aspect of the present invention there is provided a method for splitting a meal bolus between a first of a diabetes management modality and a second diabetes management modality, the method including: receiving information associated with a meal; calculating an amount of bolus insulin recommended to cover the meal based on the meal information, blood glucose data, and insulin on board information; and splitting the recommended insulin bolus amount into a first portion and a second portion to be delivered by the first modality and the second modality respectively, wherein the first portion is determined based on the amount of insulin remaining in an insulin reservoir of the first modality and wherein the second portion is determined from the difference between the recommended bolus amount and the amount of bolus insulin remaining in the reservoir of the first modality.

According to an aspect of the present invention there is provided a method for splitting a meal bolus between a first of a diabetes management modality and a second diabetes management modality, the method comprising: providing information associated with a meal at the end of a fasting time period during which a first modality of diabetes management therapy was providing automated correction bolusing; receiving instructions to deliver an amount of insulin with a second modality of diabetes management, wherein the amount is a portion of a total bolus recommendation to cover the meal; and removing the first modality from a body after delivery of a remaining portion of the total bolus recommendation, wherein the remaining portion is the difference between the total bolus recommendation and the amount instructed for delivery by the second modality.

According to an aspect of the present invention there is provided a personalized episodic use of a first diabetes management modality with a second diabetes management modality for use by a

patient within a 24 hour time period, wherein the first modality includes a wearable insulin reservoir that enables automated insulin delivery for correction boluses during a fasting time only period, and wherein the second modality includes one or more non-wearable insulin delivery devices that enable multiple daily intervention by the patient of basal insulin and/or bolus insulin, the method comprising: receiving first data associated with use of a first diabetes management modality; receiving second data associated with use of second diabetes management modality; and processing data associated with first and second modalities to provide a recommendation of an adjustment of a therapy or therapy parameters for use with one or both of the modalities.

According to an aspect of the present invention there is provided a personalized episodic use of a first diabetes management modality with a second diabetes management modality for use by a patient within a 24 hour time period, wherein the first modality includes a wearable insulin reservoir that enables automated insulin delivery for correction boluses during a fasting time only period, and wherein the second modality includes one or more non-wearable insulin delivery devices that enable multiple daily intervention by the patient of basal insulin and/or bolus insulin, the method comprising: wearing the first diabetes management modality for a first section of a 24 hour time period, wherein the first modality provides automated insulin delivery for correction bolusing during fasting; utilizing a second diabetes management modality during a second section of the 24 hour time period, wherein the second modality provides multiple daily intervention of basal insulin and/or bolus insulin, and wherein the first and second sections are not substantially overlapping; and receiving a recommendation of an adjustment of a therapy or therapy parameter for use with one or both of the modalities.

According to an aspect of the present invention there is provided a fasting hyperglycemia management system/method for delivering correction micro-boluses of insulin to a subject intended for a time period of fasting/wear based on an assumption of basal insulin sufficiency provided by external injection or ingestion of daily basal insulin, the system/method comprising: a wearable insulin delivery device for delivering correction micro-boluses of delivery device insulin during a time period of intended fasting, wherein the controller is set with a fixed zero basal rate for the duration of wear. A micro-bolus correction may be a portion of a bolus dose required to gradually bring a user's blood glucose to a target blood glucose.

According to an aspect of the present invention there is provided a fasting hyperglycemia management system/method for delivering correction micro-boluses of insulin to a subject intended for a time period of fasting based on an assumption of a meal bolus insulin provided by external injection or inhalation of meal bolus insulin, the system/method comprising: a wearable insulin delivery device for delivering correction micro-boluses of device insulin during a time period of intended fasting, and an insulin delivery controller configured to calculate a correction micro-

bolus of device insulin uninformed by external IOB.

According to an aspect of the present invention there is provided a wearable insulin delivery device for delivering correction doses of insulin during a wear period of intended fasting including an insulin delivery controller configured to iteratively calculate insulin based on $((\text{Current_BG} - \text{Target_BG})/\text{ISF}) - \text{IOB}$, wherein the system is only informed with an initial ISF of the user and periodic blood glucose measurements. The delivery device is uninformed by: an amount of insulin to be delivered, a duration of insulin action, a target blood glucose, a basal rate, an IOB, a, insulin to carbohydrate ratio.

Features and elements of an aspect of the disclosure may be included in other aspects of the disclosure to form different embodiments of the systems, devices, methods, and computer program products.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings. Described features or elements of an embodiment may be used in other embodiments within the scope of the aspects of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Figure 1A is a schematic diagram illustrating an example embodiment of an overall therapy arrangement in which the present disclosure is implemented;

Figure 1B is a flow diagram of an example embodiment of a method of insulin management according to an aspect of the present disclosure;

Figure 1C illustrates an overall time period in which two different modes of insulin management may be used in a non-overlapping manner, in accordance with some example embodiments;

Figures 2A to 2C are flow diagrams of example embodiments of methods of controlling delivery of insulin according to aspects of the present disclosure;

Figures 3A to 3D are graphs illustrating example methods of processing blood glucose measurements according to aspects of the present disclosure;

Figure 4 is a block diagram of an example embodiment of a system of controlling delivery of insulin according to an aspect of the present disclosure;

Figures 5A to 5C are flow diagrams of example embodiments of methods of use of a delivery device for controlling delivery of insulin according to aspects of the present disclosure;

Figures 6A to 6M are a series of schematic diagrams illustrating an example embodiment of a delivery device according to an aspect of the present disclosure;

Figures 7A and 7B are flow diagrams of example embodiments of methods provided by a computer application for interacting with a delivery device for controlling delivery of insulin

according to an aspect of the present disclosure;

Figure 7C is a swim-lane flow diagram illustrating an example use case for controlling delivery of insulin during a fasting period and/or for coordinating such fasting period insulin management with another therapy modality utilized during a non-fasting period, according to some example aspects of the present disclosure;

Figure 8 is a block diagram of an example embodiment of a system providing a computer application for interacting with a delivery device for controlling delivery of insulin according to an aspect of the present disclosure;

Figure 9 illustrates an example of a computing device in which various aspects of the disclosure may be implemented;

Figures 10A to 10E are graphs illustrating example patient storylines during a method of controlling delivery of insulin according to an aspect of the present disclosure; and

Figures 11A to 11C are a block diagram, flow diagram, and graph illustrating a further embodiment of a glucagon delivery device according to further aspects of the present disclosure.

DETAILED DESCRIPTION WITH REFERENCE TO THE DRAWINGS

This disclosure describes medicament management methods, systems, and delivery devices for delivering a medicament (e.g., insulin and/or glucagon) from a wearable automated medicament delivery device. The medicament delivery device may be used during a fasting period of, for example, less than about 12 hours, where the wearable automated medicament delivery device is configured and intended to be utilized only during the fasting period. Where the automated medicament delivery device is configured to dispense insulin, the device may be considered an automated insulin delivery device, or AID device. Several embodiments are described below in connection with insulin delivery. However, the present disclosure is not so limited and also contemplates similar or identical embodiments configured for delivering any other medicament affecting blood glucose levels, e.g., glucagon for increasing blood glucose concentrations when they fall below predetermined levels, for example, during sleep, or athletic or otherwise energetically demanding physical activity. In such embodiments for dispensing glucagon, a fasting period may be a period of exercise or activity.

Diabetics, by definition, are unable to regulate blood sugar properly due to substantially complete lack of endogenous insulin secretion (in Type 1 diabetics) or due to insufficient endogenous insulin secretion (in Type 2 diabetics). Accordingly, diabetics require insulin management procedures for maintaining blood glucose levels within desired target ranges essentially at all times. Accordingly, managing automatic insulin delivery only during daily fasting periods, for example when sleeping, presents several unique challenges.

First, a user must integrate a supplementary method of insulin administration outside the fasting

period (e.g., multiple daily insulin injections to cover basal and meal bolus requirements) but tracking of insulin administration between multiple modes of insulin delivery can be cumbersome for users. Second, since there is a transition between the supplementary non-fasting mode of insulin delivery and the automatic fasting mode of insulin delivery twice each day, it may be desirable to engage and disengage the automatic fasting mode at the proper times (e.g., engage at the start of the fasting period and disengage at the end of the fasting period) but natural variations in timing and duration of these fasting or sleeping periods from day to day makes determining proper times for engagement and disengagement difficult. Third, since automatic insulin administration only during the fasting period generally occurs while the user is sleeping and fasting, it is very important to guard against over-dispensing insulin and resultant hypoglycemic events during the fasting period, but this requires accurate accounting of insulin that is already in the user's system at the start of the fasting period and users are not always good at accurately estimating or accounting for actual insulin on board, especially as the time since the last manual insulin injection increases and that on-board insulin is progressively metabolized by the body.

Moreover, the majority of patients with diabetes (Type 1 and Type 2) continue to rely on multiple daily injections (MDI) therapy for diabetes management. Unfortunately, while there are many good reasons that patients may choose MDI therapy, nighttime control (as compared with automated insulin delivery (AID)) remains a missing element. Up until now, nighttime only use of AID has been impractical or even unachievable because set up of traditional insulin pump therapy (especially with AID) is a highly complex process that requires significant start up time. Additionally, continuous subcutaneous insulin infusion (CSII) is designed for infusion of basal and/or background insulin at predetermined rates rather than for use with exogenous basal insulin. For example, traditional AID includes delivery of basal and/or background insulin at predetermined, preset, and/or default rates that are not calculated or adjusted in real-time (or substantially in real-time) based on real-time (or substantially real-time) glucose values. Such basal, baseline and/or background insulin infusion would conflict with daily basal pen doses, and is not practical for twice a day transitions. Furthermore, transitioning from AID to pen and back would often leave some active insulin in your body during the changeover, which current systems aren't equipped to handle.

Aspects of this disclosure solve each of these potential problems, among any number of potential others, as described below, including through methods, devices and systems for integrating a supplementary method of insulin administration outside the fasting period; methods, devices and systems for controlling insulin administration during a fasting period using events indicative of a start and/or end of the fasting period; and/or methods, devices and systems for automated calculation and delivery of correction doses of insulin during the fasting period to, thereby, provide

a simplified, safe and effective management of time in range (TIR) during extended fasting periods. While embodiments described herein may be directed toward one or more of the above-described challenges, the present disclosure contemplates utilizing and/or incorporating any feature or features from any embodiment or embodiments with any feature or features from any other embodiment or embodiments described herein.

Methods described herein solve, among other problems, the problem of transition complexity for transient use by providing a simplified system that allows for ease of transition between two different diabetes management modalities. In one implementation, the systems and methods described herein enable seamless, intermittent, episodic use of MDI for basal insulin during day cycles and AID during night cycles, thereby allowing users to benefit from low costs, high flexibility, and improved clinical outcomes. For example, diabetes management therapy with daily basal and daytime bolusing are accomplished by MDI therapy, while overnight glucose control is achieved by a short-term wear insulin pump that provides AID control during fasting to allow the user to sleep well and wake in a target glucose range without awakening for correction bolusing.

Embodiments of insulin management methods, systems, and delivery devices are described for delivering insulin during a fasting period from a wearable automated insulin delivery (AID) device designed and intended to be worn for only the fasting period. A delivery algorithm is provided for automated calculation and delivery of correction doses. This provides a simplified, safe and effective management of time in range (TIR) during a fasting period, for example, of less than about 12 hours. The fasting time may be a time period of intended fasting. This may be at night time or any time period wherein only correction bolusing is needed in additive sense to any existing basal therapy and meal bolus therapy, which may still be “on board” throughout the fasting time period. The fasting time may be the time that a user is asleep in a daily cycle. For most users, the fasting time may be a night-time period of between 6 and 12 hours, when the user is typically lying down in a restful position and does not eat during this time.

The described insulin management embodiments are based on a user receiving insulin from a non-fasting insulin management modality during a non-fasting period within an overall time period. The non-fasting period may be the time that a user is awake in a daily cycle; however, the non-fasting period may include short periods of sleep, such as a day-time nap. The fasting period and the non-fasting period may together form an overall time period, such as a 24 hour time period or other regular overall time period for users that have non-day based cycles (for example, shift workers). The non-fasting insulin management modality provides basal doses of insulin and bolus doses of insulin. The overall time period may be 24 hours as this is a usual daily routine for users; however, the overall time period may be adjusted for users who require different schedules, for example, due to shift work. The non-fasting insulin management modality and the fasting period

insulin delivery device are intended for adjunctive use without the use overlapping. For example, doses will not typically be given from the non-fasting insulin management modality during wear of the fasting period insulin delivery device. However, the doses applied by the two therapy methods may stay in the body as insulin on board during the other therapy.

Embodiments of the insulin management method delivers insulin from a fasting insulin delivery device during a fasting period within the overall time period with the fasting insulin delivery device in the form of an automatic insulin delivery device attachable to a user's body for the duration of the fasting period. The fasting insulin delivery device delivers fast-acting insulin to correct high blood glucose measurements during the fasting period gradually over the fasting period and these are referred to as correction bolus doses. The fasting insulin delivery device delivers correction bolus doses in response to received blood glucose measurements when compared to a target blood glucose. The fasting insulin delivery device refrains from administering background basal doses as basal doses are assumed to be taken during the non-fasting portion from the non-fasting insulin management modality. For a non-fasting insulin management modality in the form of injections, the basal dose may be provided by long-acting insulin taken once or twice a day.

A wearable AID device may be in the form of a fasting-time wear only pump, for example, a night-time wear only pump. An example of a suitable pump is provided in PCT Patent Application No. PCT/IB2021/060206 (International Publication No. WO 2022/097057), the contents of which is incorporated herein by reference. The fasting-time wear pump delivers rapid-acting insulin in small correction doses. As there are no meals to cover in the fasting period, the small correction doses can be given gradually and safely to keep the user in a target range. Various safe-guards are provided in the delivery algorithm to ensure that there is no over-correction. As no basal dose is given by the fasting-time wear pump, unlike with continually worn pumps, it is not possible to turn off a basal dose to accommodate over-correction.

The described embodiments of delivery algorithms are designed to perform only minor correction bolusing while the user is fasting for a limited time period. No meal bolusing or basal rate delivery is provided. The delivery algorithm calculation is simplified and may be based on a maximum amount of insulin in the pump's reservoir allowed to be delivered with a maximum dose amount per calculation period. This is informed by periodic blood glucose measurements of the user to allow for safe and effective delivery of correction boluses of insulin without the need for information relating to basal rates, carbohydrate ratios, or insulin action time. The correction boluses correct changes in blood glucose not otherwise corrected for by basal or bolus insulin doses given during the non-fasting time (for example, daytime), which vary based on daily activities, meal consumption and overall health.

In the following description, various embodiments of methods, systems, and devices are described with reference to the figures. Described individual features of each of the embodiments may be used in other embodiments. Where the methods are described in flow diagrams, with features described by steps in the flow diagram the following may apply. One or more of the described individual features of a method may be accomplished by a single step. Individual features described as a single method step may be carried out by more than one step. Portions of the described individual features may overlap. The order of features of the methods may also be changed. In computer-implemented methods, it will be understood that each block of a flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, may be implemented by computer readable program instructions.

Figure 1A is a schematic diagram which illustrates an example embodiment of an overall therapy arrangement (100) in which the described insulin management method of a fasting-time wear delivery device (130) is used. A user (101) is shown in a sleeping position with a continuous glucose monitor (CGM) (105) attached to their body (102). The CGM (105) may take and transmit blood glucose measurements to a base station or mobile computing device (120). The user (101) may use an insulin pen (110), such as a smart-pen, or other MDI method during the daytime, i.e. during non-fasting period (162) of Figure 1C. The user (101) may use a mobile computing device (120) for managing their insulin usage. The mobile computing device (120) may be a dedicated computing device for cooperation with the delivery device (130). Alternatively, the mobile computing device (120) may be a multi-purpose computing device, for example, a smart phone. In one embodiment, a known application (121) provided by the mobile computing device (120) may receive blood glucose measurements from the CGM (105) and may manage daytime MDI therapy, for example, by interaction with an insulin pen (110).

The described arrangement provides a fasting-time wear delivery device (130) that is attached to the user's body (102) only during a fasting time. The fasting time is typically during the night-time, but other times may be fasting times, for example, if the user is a shift-worker. Typically, a fasting time is less than approximately 12 hours. The fasting-time wear delivery device (130) delivers rapid-acting insulin in small correction doses based on periodic blood glucose measurement from a CGM (105). Fasting-time wear delivery device (130) is utilized only during fasting period (164) as shown in Figure 1C below. Fasting-time wear delivery device (130) is configured to deliver rapid-acting insulin in small correction doses (180a-180e) based at least in part on periodic blood glucose measurement from CGM (105). In some embodiments, CGM (105) may be incorporated into delivery device (130). In other embodiments, CGM (105) may be a separate CGM worn by the user day and night. An insulin delivery system for implementing insulin management methods as described herein may include a controller of the insulin delivery device (130) in combination

with any other computing devices that are used to carry out a delivery algorithm, for example, the mobile computing device (120) and/or a cloud computing system (140).

In some embodiments, the fasting-time wear delivery device (130) may be provided as a kit. The fasting-time wear delivery device (130) may have a durable unit into which a disposable dispensing unit is fitted containing the insulin. The delivery device (130) may include a disposable portion including a reservoir configured to contain insulin and configured to automatically deliver the correction bolus doses to the user. The delivery device (130) may have an applicator (135) for filling and application to the user's body (102) as described further below. The durable unit may be chargeable with a charger (for example, a charging station) (131) provided for charging the durable unit during a non-fasting time, so as to be ready for re-use.

The durable unit includes a controller (132) for controlling the delivery of insulin from the delivery device (130) according to a delivery algorithm described herein. The delivery algorithm may be provided entirely on the controller (132). The controller (132) may be provided in the form of software and/or hardware components. In a first alternative embodiment, the delivery algorithm may be provided remotely instructing delivery amounts to the controller (132). The delivery algorithm may be provided remotely from a cloud computing system (140) or server, from a computer application (122) or other software on a user's mobile computing device (120), or from another form of computing device or system. In a second alternative embodiment, the delivery algorithm may be distributed with different steps or functions carried out by one or more of: the controller (132), a cloud computing system (140), software on a mobile computing device (120), and another form of computing device or system.

Referring to Figure 1B, a flow diagram (150) shows an example embodiment of an insulin management method. The method delivers (151) insulin from a non-fasting insulin management modality during a non-fasting period within an overall time period. The non-fasting insulin management modality provides basal doses of insulin and bolus doses of insulin. A first therapy, a non-fasting insulin management modality, may include any mode, method, device process, therapy, or the like that is used as an intervention in diabetes therapy, including but not limited to a pump delivery of insulin (other than fasting period delivery device (130)), MDI pen or syringe injections of insulin, inhaled insulin, oral insulin, or any form of insulin management used when the user is awake. The non-fasting insulin management modality may also include diet and exercise where insulin is managed, at least some of the time, without medicinal intervention. In some embodiments, the non-fasting insulin management modality may also, or alternatively, include any oral medication for Type 1 or Type 2 diabetes, for example and not limitation, GLP-1 and metformin.

The method includes delivering (152) insulin from a fasting insulin delivery device during a fasting period within the overall time period. This may be considered to be an adjunctive therapy to the first therapy. The fasting insulin delivery device is an automatic insulin delivery device attachable to a user's body for the duration of the fasting period that delivers correction bolus doses in response to received blood glucose measurements and refrains from administering any background basal doses of insulin. The user is not required to interact with delivery device (130) for correction of bolus insulin during the fasting period, when the user is typically asleep. In some embodiments, the time period of intended fasting may be from up to about 2 hours before the user goes to sleep and until about 2 hours after waking. Correction bolus doses are amounts of insulin to be delivered in addition to the basal insulin and meal bolus insulin provided by the non-fasting insulin management modality during the non-fasting period. The amount of a correction bolus may be determined when glucose is above a target level and may be based on a difference between a current blood glucose and a target blood glucose as well as insulin sensitivity factor and an amount of insulin on board, if available. The correction dose may be delivered at a maximum rate per interval to provide a gradual correction and to avoid hypoglycemia risk.

The method may base (153) the correction bolus doses in the fasting period on a user's insulin sensitivity factor (ISF). ISF is a quantified variable of a personalized variable and is a measure of how much one unit of insulin is expected to lower blood sugar by for the user. For example, if 1 unit of insulin will drop blood sugar by 25 mg/dL, then insulin sensitivity factor is 1:25. The ISF may be derived from a total daily basal dose information received from the non-fasting insulin management modality in a defined period prior to the fasting period. Alternatively, the ISF of the user may be known, for example, through use of another insulin therapy. In another option, the ISF of the user may be learned during use of the delivery device. The ISF may be a single ISF for the user fixed for the duration of the delivery. In alternative embodiments, an ISF profile may vary over time as a user's ISF may vary for different times of the day, for example, many people are more insulin resistant in the morning, which requires a stronger correction factor. The ISF profile may be use a learning algorithm that is adjusting the ISF. This may be adjusted during a delivery session or for a next delivery session.

The method may include, at the start of the delivery from the fasting insulin delivery device, determining (154) an assumed insulin on board. The assumed insulin on board may be based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose. The assumed or hypothetical dose may be applied in the dose calculation as an assumed insulin on board. Alternatively, if the initial insulin on board is known, for example, through use of another insulin therapy, this may be used as the assumed insulin on board.

Delivering (152) insulin from a fasting insulin delivery device during a fasting period may include using a dose calculator at each blood glucose measurement timepoint to determine when insulin is required to bring the user to a target blood glucose. The dose calculator may compare a blood glucose value to a target blood glucose to obtain a difference that is adjusted by a user insulin sensitivity factor, wherein a resultant dose amount is compensated by a determined insulin on board. The determined insulin on board is a combination of the assumed insulin on board and a known delivered insulin from the delivery device during the fasting period once insulin is delivered.

The received blood glucose measurements may be smoothed with a low pass filter to reduce the effect of noise and/or abrupt perturbations to obtain blood glucose values. Where the received blood glucose measurements are trending downward over time, the downward trend may be projected forward and added to the blood glucose value used in the dose calculator. The correction bolus doses for a fasting period may be limited to a defined maximum dose given at any time point to minimize sudden corrections. A default to a dose of zero may be incorporated.

Example embodiments of a method of calculating one or more correction doses are described below. The amount of a correction bolus may be determined when glucose is above a target level and may be based on a difference between a current blood glucose and a target blood glucose as well as insulin sensitivity factor and an amount of insulin on board. The insulin correction dose calculation is determined at least in part utilizing equation (1) below and, in some cases, further applying one or more safety factors to one or more of the variables utilized therein, as described anywhere in this disclosure, to effectively guide a user's blood glucose toward a target range and then maintain the user's blood glucose at or near the target during a fasting period.

$$(1) \quad \text{Dose_Calculation} = [(Current_BG - Target_BG) / ISF] - IOB$$

The Dose_Calculation is a calculated amount of additional insulin needed to decrease a user's current blood glucose level to a target blood glucose level as described anywhere in this disclosure. The Current_BG is a measured blood glucose value of the user that may be evaluated before applying in equation (1) as described anywhere in this disclosure. The Target_BG is a target for the user's blood glucose level. ISF (insulin sensitivity factor) is a user-specific factor indicating how many milligrams per deciliter (mg/dl) one unit of insulin is expected to lower the user's blood glucose.

An insulin delivery system for implementing an insulin management method is defined as including a controller of the insulin delivery device (130) in combination with any other computing devices that are used to carry out the delivery algorithm. In some embodiments, the controller may carry out all the processing of the delivery algorithm and in other embodiments this may be distributed to other processing devices. The insulin delivery system may include the delivery

device (130) with a controller for controlling the delivery of insulin from the insulin delivery device with the insulin in the form of a plurality of correction bolus doses during a fasting period in response to received blood glucose measurements. The correction bolus doses may be compensated for by a determined insulin on board and where for at least a first correction bolus dose of the plurality of correction bolus doses the determined insulin on board equals the assumed insulin on board. The insulin delivery system may include the delivery device and/or other computing systems that carry out some of the delivery algorithm processing. For example, to determine an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose.

FIG. 1C illustrates an example of an overall time period (160) in which a plurality of different modes of insulin management may be used in a non-overlapping manner, in accordance with some example embodiments. In some situations, overall timer period (160) may be 24 hours in length, as is a usual daily routine for most users. However, the overall time period (160) may be adjusted for users who require different and sometimes more erratic schedules, for example, due to shift work. The described insulin management is based on a user receiving insulin from one or more non-fasting insulin management modalities (e.g., an insulin pen (110) as shown in or described in connection with Figure 1A) during a non-fasting period (162) of the overall time period (160) and receiving insulin from a different fasting insulin management modality (e.g., fasting-time wear delivery device (130) as shown in or described in connection with Figure 1A) during a fasting period (164) of the overall time period (160).

As described herein, the non-fasting insulin management modality and the fasting period insulin management modality are intended for adjunctive, e.g., supplemental, use without the non-fasting and fasting modalities actively overlapping. For example, as will be described below, neither basal insulin dose(s), e.g., (170a, 170b), nor meal bolus doses (172a-172d) will typically be given from the non-fasting insulin management modality during the fasting period (164) and correction doses (180a-180e) will typically not be given from the fasting insulin management modality during the non-fasting period (162). Accordingly, once non-fasting period (162) has commenced the fasting period insulin management modality is not intended for use, and once fasting period (164) has commenced, the non-fasting insulin management modality is not intended for use. However, at least part of the basal doses (170a, 170b) or meal bolus doses (172a-172d) administered during the non-fasting period (162) may still be active in the body, as insulin on board, during the fasting period (164). Correction doses (180a-180e) during a fasting period (164) are supplemental to meal boluses (172a-172d) given during non-fasting period (162), for example, when meal boluses (172a-172d) have not sufficiently covered the rise in glucose resulting from a meal or when glucose otherwise remains elevated after meals or meal bolusing. This non-sufficiency may

be due to errors in bolus calculation, errors in reported meal information, errors in therapy parameters used for therapy calculations, hormonal factors, and the like.

The non-fasting period (162) may be the time that a user is awake in a daily cycle; however, the non-fasting period (162) may include short periods of sleep, such as a day-time nap. The fasting period (164) may be a time period of intended fasting. This may be at nighttime or any time period wherein only correction bolusing is needed in additive sense to any existing basal therapy and meal bolus therapy, which may still be “on board” throughout the fasting time period (164). Accordingly, the fasting period (164) may be the time that a user is asleep in a daily cycle. For most users, the fasting period (164) may be a night-time period of between 6 and 12 hours, and typically less than 22 hours, when the user is typically lying down in a restful position and does not eat during this time.

In Figure 1C, basal doses (170a and/or 170b) and meal bolus doses (172a-172d) are administered via the non-fasting insulin management modalities during the non-fasting period (162). Basal insulin is the background insulin that a diabetic person needs to maintain blood glucose in a desired range in the absence of meals during the non-fasting period (162). While needs vary by user, basal insulin typically comprises approximately 50% of the total insulin needs of somebody with Type 1 diabetes. Basal dose(s) (170a, 170b) may comprise slow-acting insulin. Where one basal dose (170a) is administered per day, dose (170a) may be configured to fulfill the user's 24-hr basal requirements for insulin and may be administered by daily injection of insulin administration during the non-fasting period (162), for example via insulin pen (110) (see, e.g., Figure 1A). Where two basal doses (170a, 170b) are administered per day, doses (170a, 170b) may each be configured to fulfill the user's 12-hr basal requirements for insulin and doses (170a, 170b) may be administered by a multiple daily injection (MDI) mode during the non-fasting period (162).

By contrast, a meal bolus dose is an amount of insulin needed to compensate for an expected rise in glucose in a person with diabetes resulting from eating food, where the compensation aims to bring blood glucose into a target range. Typically, a user eating some amount of carbohydrates requires insulin to avoid resulting elevated glucose. Figure 1C illustrates meal bolus doses (172a-172d) administered by the MDI mode during the non-fasting period (162). In contrast to basal dose(s) (170a, 170b), meal bolus doses (172a-172d) may comprise fast-acting insulin. While a certain number of meal bolus doses are illustrated in non-fasting period (162), they are for example only and any number of doses are contemplated as required by the number of meals eaten during the non-fasting period (162).

During the fasting period (164) within the overall time period (160), the described insulin management method delivers insulin from a fasting automatic insulin delivery (AID) device attachable to a user's body for the duration of the fasting period (164), for example, a night-time wear only pump as provided in PCT Patent Application No. PCT/IB2021/060206, the contents of which are incorporated herein by reference. Such a device (130) is illustrated in Figure 1A, as will be described in more detail below. Since no meals are eaten during the fasting period (162), the device (130) is configured to deliver fast-acting insulin, in the form of correction bolus doses or micro-bolus doses (180a-180e), to gradually correct high blood glucose measurements during the fasting period (164) and, thereby, allow the user to sleep well and wake in a target glucose range without awakening for correction bolusing. While a certain number of correction bolus doses are illustrated in fasting period (164), they are for example only and any number of correction doses are contemplated as required during the fasting period (164).

Basal doses (170a, 170b) are assumed to be taken during non-fasting period (162) from the non-fasting insulin management modality. Notably, fasting insulin delivery device (130) refrains from administering background and/or basal insulin to the user. Specifically, fasting insulin delivery device (130) does not allow for any preset default, basal or background doses of fast-acting insulin delivery, for example, to account for a user's basal insulin needs. In other words, in contrast to the operation of conventional CSII devices, delivery device (130) does not allow a preset basal rate of basal insulin delivery or a preset pattern of basal insulin delivery, for either fast- or slow-acting insulin. Delivery device (130) also does not store such preset basal rates or preset patterns of basal insulin delivery, fast- or slow-acting. Delivery device (130) does not deliver background insulin whatsoever. Therefore, background, baseline and/or basal rates of basal, baseline and/or background insulin delivery are unalterably fixed at zero, as insulin delivery device (130) may be specifically configured to be incapable of such basal, baseline and/or background insulin delivery. Accordingly, fasting insulin delivery device (130) is designed to perform only minor correction bolusing while the user is fasting for a limited time period and, in contrast to CSII devices, cannot deliver any insulin dose without first running an insulin correction dose calculation that is based on true and/or evaluated real-time (or substantially real-time) blood glucose values, as described anywhere in this disclosure. And in some embodiments, fasting insulin delivery device (130) is also not configured for meal bolus delivery whatsoever. This configuration greatly simplifies the requirements for delivery algorithms to enable fasting insulin delivery device (130) to effectively maintain blood glucose in a target range without the need for information relating to basal rates, carbohydrate ratios, or insulin action time.

As will be described in more detail below, a delivery algorithm tasked with determining the size of correction doses (180a-180e) employs various safety factors to adjust one or more variables and ensure that there is no over-administration of insulin or attendant over-correction of blood glucose

during non-fasting period (162). Moreover, since the user must integrate the non-fasting mode of insulin administration outside the fasting period, one or more systems, devices and methods disclosed herein may also provide functionality that integrates this supplementary method of insulin administration, utilized outside fasting period (164), with the automatic fasting insulin delivery method of insulin administration utilized during fasting period (164). In some embodiments, to aid efficient transition between this supplementary method of insulin administration during non-fasting period (162) and the automatic corrective method of delivery during fasting period (164), one or more systems, devices and methods disclosed herein may also be configured to accurately detect one or both of a starting activity (190) (Figure 1C) indicative of a need, desire, or appropriateness for initiating automated delivery of insulin from insulin delivery device (130) at or temporally near the beginning of fasting period (164), and an ending activity (192) (Figure 1C) indicative of a need, desire, or appropriateness for terminating automated delivery of insulin from insulin delivery device (130) at or temporally near the end of fasting period (164), as will be described in more detail below.

Referring to Figure 2A, a flow diagram (200) shows an example embodiment of a method of management of insulin by a delivery device, for example, such as the delivery device (130) of Figure 1A. The method may be carried out by a controller of the delivery device or with some of the steps carried out remotely to the controller. The method may be carried out in cooperation of the controller with a user application provided on a user's mobile computing device.

The method may include detecting (201) a starting activity associated with preparation of use of an insulin delivery device in the form of an AID attachable to a user's body for a duration of a fasting period within an overall time period. The detecting (201) of a starting activity associated with preparation of use of the delivery device may include various different forms of detection of preparing the delivery device prior to a readiness to deliver insulin. Such a starting activity may be any activity indicative of a need, desire, or appropriateness to initiate automated delivery of insulin from the insulin delivery device (130). Automated delivery may be initiated without explicit instructions from the user. For example, in some embodiments, such a starting activity may be any activity that is not a direct action to automate delivery, for example pressing a power button, but is, instead, an activity that commonly occurs or would be expected to commonly occur before or substantially at the beginning of fasting period. In this way, such starting activities have a primary function other than initiating automated delivery of insulin from the insulin delivery device (130) such that those starting activities are used for their primary function and also, simultaneously reused to effectively and accurately indicate of a need, desire, or appropriateness to initiate automated delivery of insulin because the starting activities are also activities whose occurrence has a significantly higher correlation with the start of fasting period. This solves at least the problem of transition complexity for transient use by providing a simplified system that

allows for ease of transition between two different diabetes management modalities.

For example, as will be described in more detail below, starting activities may include but are not limited to physical activities carried out by the user in relation to the delivery device, physical changes to the delivery device, activity level of the user satisfying predetermined criteria, and/or occurrence of a pre-set time of the day. The user carrying out such starting activities, and/or detection of such starting activities by one or more devices and/or device components as described herein may play a role in one or more processes for managing insulin delivery using differing modalities during the non-fasting period compared to the fasting period as described anywhere in this disclosure.

The delivery device (130) may detect its own activation, for example and not limitation, when the user starts to wear device (130). Alternatively, where one or more steps and/or calculation procedures are carried out remotely by another device, such as mobile device (120) or remote cloud device (140), such a method may include detection or receiving notification, by the other device, of such activation of delivery device (130). In one example, detecting (201) a starting activity may be the receipt of the first blood glucose measurement. For example, in some embodiments, activation component (446) of delivery device (401) of Figure 4 may be configured to perform such detection.

The detecting (201) may include detecting one or more physical activities carried out by the user in relation to the delivery device. The physical activities may include one or more of: removing a controller of the delivery device from a charger, the attachment of a dispensing unit to the controller or installation of a pre-filled insulin cartridge, application to a user's body, removal of an applicator from the controller, completion of a manual priming sequence, or a sound or voice command to the controller. The detecting (201) may also be at a pre-set time of the day or may be triggered by an activity level of the user detected by the delivery device or another monitor, such as a fitness monitor detecting a period of rest.

The detecting (201) may include detecting physical changes of the delivery device. The physical changes may include: detecting a movement of the controller due to an accelerometer in the controller, a proximity or pairing of the controller to a user computing device, such as a smart phone, at which a user application is provided, detecting a proximity of a smart pen when filling the dispensing unit, detecting a connection of a dispensing unit or cartridge to the controller, detecting fill level of an insulin reservoir by the controller, detecting a removal of an applicator from the controller, detecting removal of the controller from a base, detecting movement of a plunger in the dispensing unit, detecting an auto-priming of the delivery device. Any of these examples of detecting a starting activity may serve a function of transforming one or more physical

activities of the user and/or physical changes of the delivery device into one or more electrical signals and/or physical configurations of one or more electrical components indicative of a need, desire, or appropriateness for initiating automated delivery of insulin from the insulin delivery device.

By way of example and not limitation, removal of delivery device (130) from charger (131) has a primary function of discontinuing charging of delivery device (130), not initiating a fasting period. However, since device (130) is worn by the user during fasting period, discontinuation of charging, removal from charger (131), and/or detecting the physical acceleration of device (130) during such an action, has a significantly higher correlation with the start of a fasting period and, so may be reused for a purpose different than its primary purpose and to indicate initiating a fasting period.

Similarly, insulin pen (110) or mobile device (120) coming into a predetermined distance (e.g., proximity) of device (130) has a primary function of physically moving insulin pen (110) or mobile device (120), not initiating a fasting period. However, since insulin pen (110) and/or mobile device (120) may be utilized during non-fasting period, or to fill an insulin reservoir of device (130) immediately before fasting period, such an action, has a significantly higher correlation with the start of a fasting period and, so may be reused for a purpose different than its primary purpose and to indicate initiating a fasting period.

Similarly, insertion of the insulin reservoir or of a prefilled insulin cartridge into device (130) has a primary function of coupling the insulin reservoir or cartridge to device (130), not initiating a fasting period. However, the insulin reservoir and/or cartridge must be inserted into device (130) to be usable during fasting period, such an action, has a significantly higher correlation with the start of a fasting period and, so may be reused for a purpose different than its primary purpose and to indicate initiating a fasting period.

Similarly, an activity level falling to levels indicative of rest has a primary function of the user resting, not initiating a fasting period. However, since fasting period is the timeframe during which the user is expected to sleep, occurrence of the user's activity level falling to or near resting rates has a significantly higher correlation with the start of a fasting period and, so may be reused for a purpose different than its primary purpose and to indicate initiating a fasting period. Several additional examples of starting activities, each having a primary function other than initiating automated delivery of insulin from the insulin delivery device (130) such that those starting activities are used for their primary function and also, simultaneously reused to effectively and accurately indicate of a need, desire, or appropriateness to initiate automated delivery of insulin because the starting activities are also activities whose occurrence has a significantly higher

correlation with the start of fasting period.

In some embodiments, a combination of two or more starting activities are required for insulin delivery to be initiated. In some embodiments, a confirmation is requested or required, responsive to one or a plurality of starting activities, on a user interface, or the like. In some embodiments, the initiation of insulin delivery is responsive to a series of starting activities following predetermined criteria.

In some embodiments, such starting activity may comprise arrival of a pre-set time of the day and/or an activity level of the user indicative of a period of rest. Detection of such a starting activity may include various different forms of detection of preparing the delivery device prior to a readiness to deliver insulin, for example detecting one or more physical activities carried out by the user in relation to the delivery device, and/or detecting physical changes of the delivery device.

The method may initiate (202) automated delivery of insulin from the delivery device. The initiating (202) may be in response to the detection of the starting activity and may take place after a predefined time interval from the starting activity. The initiating (202) of the automated insulin delivery in response to the detected activity may include priming the delivery device to be ready to deliver the insulin. The method may deliver (203) insulin in the form of correction bolus doses in response to the received blood glucose measurements whilst refraining from administering any background basal doses of insulin. The delivery device may refrain from administering basal insulin at a preset or default rate or in a preset or default pattern. The delivery (203) may include correction bolus doses based on an assumed insulin on board based on an initial hypothetical correction bolus dose calculated to correct an initial blood glucose measurement of the user to a target blood glucose. The delivery (203) may be based on a user's insulin sensitivity factor based on a total daily basal dose delivered prior to use of the delivery device. The delivery (203) may be determined from an insulin deficit measured from the received blood glucose measurements. The amount to be delivered may be determined without a carbohydrate factor or a carbohydrate ratio known, without meal information, and without determining an insulin action time. The glucose target range may be fixed. The delivery may be zero for some fasting periods where no insulin is needed for correction.

The method may detect (204) an ending activity associated with ending the use of the insulin delivery device. An ending activity may include: detection of the removal of the wearable insulin reservoir from the body, completion of a predetermined time period of less than a defined time period (for example, 24, 12, 10, 8 or 6 hours), or a returning the durable portion of the delivery device to the charging port.

For example, delivery device (130) and/or mobile device (120) may be configured to detect such an ending activity, which may be any activity indicative of a need, desire, or appropriateness to terminate automated delivery of insulin from the insulin delivery device (130). For example, in some embodiments, such an ending activity may be any activity that is not a direct action to stop automate delivery, for example pressing a power button to turn delivery device (130) off, but is, instead, an activity that commonly occurs or would be expected to commonly occur substantially at the end of fasting period. In this way, such ending activities have a primary function other than initiating stopping automated delivery of insulin from the insulin delivery device (130) such that those ending activities are used for their primary function and also, simultaneously reused to effectively and accurately indicate of a need, desire, or appropriateness to terminate automated delivery of insulin because the ending activities are also activities whose occurrence has a significantly higher correlation with the end of fasting period. This solves at least the problem of transition complexity for transient use by providing a simplified system that allows for ease of transition between two different diabetes management modalities.

Such an ending activity may include: detection of the removal of the wearable insulin reservoir from device (130), detection of removal of device (130) from the body, completion of a predetermined time period of less than a defined time period (for example, 24, 12, 10, 8 or 6 hours), or a returning of the durable portion of delivery device (130) to charger (131).

By way of example and not limitation, removal of the insulin reservoir of delivery device (130) has a primary function of disconnecting the insulin reservoir from delivery device (130), for example, to fill the reservoir, not terminating a fasting period. However, since the insulin reservoir must be properly disposed within delivery device (130) in order for proper function, removal of the insulin reservoir has a significantly higher correlation with the end of a fasting period and, so may be reused for a purpose different than its primary purpose and to indicate terminating of fasting period.

Similarly, reconnecting device (130) to charger (131) has a primary function of charging delivery device (130), not terminating a fasting period. However, since device (130) is worn by the user during fasting period, reconnecting it to charger (131) has a significantly higher correlation with the end of a fasting period and, so may be reused for a purpose different than its primary purpose and to indicate a desire to terminate a fasting period.

Similarly, removal of delivery device (130) from the user's body has a primary function of decoupling device (130) from the user's body, not terminating a fasting period. However, since the delivery device (130) must be properly worn by the user for proper function, removal of delivery device (130) from the user has a significantly higher correlation with the end of a fasting period

and, so may be reused for a purpose different than its primary purpose and to indicate terminating of fasting period.

Similarly, an activity level rising significantly above resting levels has a primary function of the user being active, not terminating a fasting period. However, since fasting period is the timeframe during which the user is expected to sleep, occurrence of the user's activity level rising significantly above resting levels has a significantly higher correlation with the end of a fasting period and, so may be reused for a purpose different than its primary purpose and to indicate terminating a fasting period.

In some embodiments, a combination of two or more ending activities are required for insulin delivery to initiated. In some embodiments, a confirmation is requested or required, responsive to one or a plurality of ending activities, on a user interface, or the like. In some embodiments, the initiation of insulin delivery is responsive to a series of ending activities following predetermined criteria.

Any example of detecting an ending activity may serve a function of transforming one or more physical activities of the user or physical changes of the delivery device into one or more electrical signals and/or physical configurations of one or more electrical components indicative of a need, desire, or appropriateness for initiating a fast-ending procedure and/or for the user's discontinued use of insulin delivery device (130). The user carrying out such ending activities and/or detection of such ending activities by one or more devices and/or device components as described herein may play a role in one or more processes for managing insulin delivery using differing modalities during the non-fasting period compared to the fasting period as described anywhere in this disclosure.

In one embodiment, the method may coordinate (205) a fast-ending procedure for the user. The fast-ending procedure may include delivering at least a portion of a fast-ending bolus at the end of the session. For example, this may be a meal bolus. As an example, there may be times when a user wakes up with elevated glucose because the delivery was conservative assuming the user may still sleep for many more hours. In this case, a fast-ending bolus may be required which is not necessarily associated with a meal. The user may prompt a fast-ending bolus in the form of a final correction bolus. This may be only part of the required fast-ending bolus using the remaining insulin in the delivery device. A final fast-ending correction bolus may be a hybrid corrective and meal bolus, administered at or near the end of fasting period both to correct waking elevated glucose and, further, in expectation of a meal being eaten during the subsequent non-fasting period after fasting period has ended. The delivery algorithm may have numerous safeguards to avoid overcorrecting during the fasting period; therefore, once the user is awake a full correction

dose may be required.

With reference to Figure 1C, as an overall period (160) is a recurring period (e.g., a 24-hour period in some cases), the coordination of a fast-ending procedure, or if this is not included, the detection (204) of an ending activity may advance back to the step of detecting (201) a starting activity at the initiation of the non-fasting period (162) of the next overall period (160) that immediately follows the fasting period (164). Moreover, the recurring nature of overall period (160) necessitates a transition from the non-fasting period (162) and its associated mode of insulin administration (e.g., MDIs) to the fasting period (164) and its automatic administration of correction doses (180a-180e), as well as another transition back to the next non-fasting period (162) and its associated mode of insulin administration at the end of fasting period (164). Accordingly, some methods, devices and systems configured for integrating a supplementary method of insulin administration outside fasting period (164) may include coordination of one or more correction doses (180a-180e) provided by delivery device (130) during fasting period (164) with one or more basal doses (170a, 170b) or meal doses (172a-172d) provided via the non-fasting modality (e.g., insulin pen (110) of Figure 1A) during non-fasting period (162).

Referring to Figure 2B, a flow diagram (220) shows an example embodiment of a method of controlling the delivery of insulin from a fasting-time wear delivery device, for example, such as the delivery device (130) of Figure 1A. The method delivers insulin during a fasting period from the delivery device intended to be worn for only the fasting period and where no basal dose is given by the delivery device. The method may be utilized to deliver insulin during a fasting period (164) from delivery device (130) intended to be utilized only during fasting period (164). No basal doses of insulin are given by delivery device (130). Such a method may solve a problem of accounting for insulin on board from non-fasting delivery modalities without any user interaction or input, and without any prior, or direct knowledge of the amount of insulin actually administered to the user from such non-fasting delivery modalities. Such a method may be carried out at and/or by a controller, such as controller (132) of delivery device (130) shown in Figure 1A, at and/or by delivery device (401) or mobile computing device (402) as shown in Figures 4 and/or 8, and/or remotely at and/or by a server, computing device, or the like, such computing device (900) shown in Figure 9, instructions then being sent to the controller. In some embodiments, certain steps may be carried out by such an above-described controller of the delivery device and/or with some of the steps carried out remotely to the controller. Accordingly, in some embodiments, such methods may be carried out in cooperation with such an above-described controller with a user application provided on a user's mobile computing device, for example mobile computing device (401).

The method may include an initialization stage (221) in which various parameters and safety factors are set-up for the delivery algorithm. Some of the steps of the initialization stage (221) may be updated during the delivery stage. In the initialization stage (221) the method may receive or determine (222) an initial user insulin sensitivity factor (ISF). An ISF is a user-specific factor of how much one unit of insulin is expected to lower the user's blood glucose. In some embodiments, this initial ISF may be received from the user (i.e. the patient), from a doctor, or from a connected device, such as a user application or another insulin therapy device, such as smart insulin pen (110) of Figure 1A. The user ISF may be learnt and refined over time during use of the fasting-time delivery dose for repeated fasting-time periods. In some embodiments, this may be the only user input required for the method other than the periodic blood glucose measurements. This greatly simplifies user interaction with devices and systems of this disclosure. In some embodiments, ISF receiving component (431) of delivery device (401) of Figure 4 may be configured to perform the functions of the initialization stage (221).

The initial user ISF may be based on received total daily basal dose (TDBD) information. The TDBD information may be provided by the user or a doctor via a user application or smart insulin pen. TDBD or daily basal amount is the amount to basal insulin taken in a 24 hour period and it is typically constant from day to day for a user. A user's TDBD may, for example, be determined by an amount of basal insulin injected from an insulin pen in a 24 hour period. In such embodiments, receiving the ISF may include receiving TDBD (e.g., the sum of MDIs (170a, 170b) in Figure 1C) and estimating ISF from the received TDBD. For example, strong relationships exist between TDBD, total daily dose (TDD), and ISF, as set forth by formulas (2)-(4) below:

$$(2) \quad \text{ISF} = 800/\text{TDBD}$$

$$(3) \quad \text{TDBD} = 0.47 \times \text{TDD}$$

$$(4) \quad \text{ISF} = 1700/\text{TDD}$$

In some embodiments, ISF may be determined based at least in part on a body weight of the user. In some embodiments, the ISF of the user may be learned during use of the delivery device (130). In some embodiments, an ISF profile may vary over time as a user's ISF may vary for different times of the day, for example, many people are more insulin resistant in the morning, which requires a stronger correction factor. The ISF profile may use a learning algorithm configured to set and/or adjust the ISF during a delivery session or in advance for a next delivery session.

The method of the delivery algorithm determines the insulin needed to bring the user gradually to a target blood glucose. The delivery algorithm is based on calculating a correction dose of insulin by comparing an evaluated blood glucose measurement to a target blood glucose with a difference adjusted by the user ISF. The resultant correction amount may be compensated by a

determined insulin on board. The compensation may reduce the resultant dose amount by the determined insulin on board. The target blood glucose may be a set amount for all users or for different categories of users and may be time varying to decrease over time during the fasting period. The rate of decrease over time of the target blood glucose may assume that blood glucose levels are being lowered by existing externally administered insulin administered prior to the fasting period.

The method may receive (223) a first blood glucose measurement. For example, blood glucose measurements may be received periodically from a glucose monitor (e.g., CGM (105) in Figure 1A). In some embodiments, BG receiving component (451) of delivery device (401) of Figure 4 may be configured to perform the functions of block (223). As will be described in more detail below, an initial blood glucose measurement, or set of initial blood glucose measurements, at or sufficiently temporally near the beginning of fasting period (164) may be utilized to determine an assumed IOB, and in some cases one or more safety factors for variables utilized in determining correction dosing, in subsequent steps.

A target blood glucose and one or more safety factors may be set (224). The target blood glucose may be adjusted by a target safety factor to bias to a target safety factor. For example, target blood glucose may be set and then any one or more of target blood glucose, ISF and IOB may be adjusted by applying a safety factor to, thereby, ultimately steer or bias insulin dosing, or calculation of such dosing, to guard against over-delivery and inducement of hypoglycemia. The calculated correction dose may also be adjusted by an overall safety factor. One or more of these safety factors may be based on an initial blood glucose measurement or group of initial blood glucose measurements received (223) at the start of the fasting period. One or more of the safety factors may be based on a difference between the evaluated blood glucose measurement and the target blood glucose. The safety factors may be a percentage adjustment, such as 5%, 10%, 15% or 20% from a baseline value.

For example, in some embodiments, target blood glucose may be set a predetermined or constant value for all users, or at a respective one of a plurality of constant values for each of a plurality of classifications of user, at the beginning of fasting period (164). In some embodiments, target blood glucose is set based at least in part on the first blood glucose measurement received (223), for example, initially setting or adjusting target blood glucose higher for higher first blood glucose measurements and relatively lower for relatively lower first blood glucose measurements. In some embodiments, a fixed or constant valued glucose target means the method does not allow the user to manually input or modify the glucose target value. In some embodiments, target glucose levels may begin at an initial value, as here, and adjust over fasting period (164) as will be described in more detail below.

As will be described in more detail below, safety factors may also be applied to actual blood glucose measurements in the form of filtering and/or any other modification thereto as described anywhere in this disclosure. However, such adjustments are largely discussed as evaluating (229) blood glucose measurements. Similarly, application of any safety factor to the calculated resultant correction dose may be applied by limiting the correction dose based on a maximum delivery rate.

The initialization stage (221) of the method may include determining (225) insulin on board (IOB), which is how much insulin is still active inside the user's body. This may be based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose. This is described further below in relation to Figure 2C. The IOB may include an assumed insulin on board that is assumed to be provided by the non-fasting insulin therapy prior to use of the delivery device (referred to as "external insulin"). The IOB is initially assumed to be sufficient and reduced over time during the fasting period. The rate of reduction over time may be based on an assumption that glucose levels are impacted by existing externally administered insulin administered prior to the fasting period based on known decay rates or duration of insulin action in the body. The assumed insulin on board may be adjusted over time in the delivery stage when compared to evaluated blood glucose measurement. During the delivery stage, the determined IOB may also include the known delivered device insulin as known from delivered correction doses from the delivery device. The term "external insulin" refers to insulin delivered by a device other than the described fasting delivery device. The term "device insulin" refers to insulin delivered by the fasting delivery device. This is insulin to be delivered by the wearable insulin delivery device for delivering correction doses of insulin to a user intended for a time period of fasting.

An assumed external IOB is based on a hypothetical, or assumed, amount of external insulin needed to correct the user's hyperglycemia based on a comparison of current BG (or current evaluated BG) to target BG according to equation (6), as derived from equation (5) below:

$$(5) \quad [(Current_BG - Target_BG) / ISF] - IOB = 0$$

$$(6) \quad Assumed\ IOB = [(Current_BG - Target_BG) / ISF]$$

The assumed external IOB may be calculated from a difference, between current blood glucose (or current evaluated blood glucose as described anywhere in this disclosure) and the target blood glucose, scaled by the ISF, as set at block (222) and/or as adjusted at block (224) and not derived from known external insulin. In some embodiments, the first blood glucose value(s) on which the assumed IOB is based may be averaged over a set of first blood glucose measurements to filter transient and/or acute changes. In some embodiments, such a set of first blood glucose measurements may be filtered to exclude outlier values and/or excluding such outlier values from

being used in such a rolling average. As described above, accounting for an assumed initial IOB sufficiency means the controller does not need to accept or use a known amount of external IOB info from the user. Accordingly, the correction dose calculation may be accomplished without any external IOB input or knowledge whatsoever. The assumed IOB for at least an initial period does not include insulin input from any previous dosing. An initial assumed IOB determined from equation (5) above is also simpler for the user and reduces user error.

Moreover, assumed IOB may also function as a safety factor in that the IOB in equation (5) is initially assumed, or set, equal to assumed IOB. In this way, when such a safety factor is embodied as an assumed external IOB that decays over time, any dose calculation over 0 going forward (or a minimum threshold that delivery device (130) is configured to deliver, such as 0.1 units of insulin) represents an unexpected BG, or incomplete external IOB, which may be safely compensated for by delivering the difference (e.g., 0.1 unit insulin).

The correction bolus doses are compensated for by a determined insulin on board and, for at least a first correction bolus dose of the plurality of correction bolus doses, the determined insulin on board equals the assumed insulin on board. The method in the initialization stage (221) may deliver (226) the first dose that may be zero units based on the assumption of assumed IOB sufficiency. For example, as stated above, assumed IOB is initially determined based the assumption of initial IOB sufficiency. Accordingly, the first correction dose, during and/or at the end of initialization stage, would not include any insulin delivery.

The method may include a delivery stage (227) in which blood glucose measurements are received periodically (228). For example, the blood glucose measurements may be received from a glucose monitor such as CGM (105) in Figure 1A. In some embodiments, BG measurement receiving component (451) of delivery device (401) of Figure 4 may be configured to perform the evaluation. In other embodiment, the CGM (105) may carry out at least some of the functionality of the evaluation.

Guarding against over-delivering insulin or guarding against calculating to over-deliver insulin may be better achieved by utilizing a processed, evaluated and/or filtered proxy of the user's actual blood glucose levels that more accurately represents the long-term trends of the user's actual blood glucose levels while also attenuating, eliminating or otherwise filtering out short-term noise and/or aberrations. Accordingly, the periodically received blood glucose measurements (or a subset thereof) may be evaluated (229) using various different methods. For example, the periodically received blood glucose measurements may be processed and/or filtered as described below or anywhere else in this disclosure in order to obtain a proxy of the user's actual blood glucose levels that more accurately represents the long-term trends of the user's actual blood

glucose levels while also attenuating, eliminating or otherwise filtering out short-term noise and/or aberrations.

In some embodiments, the blood glucose measurements may be evaluated (229) by smoothing received blood glucose measurements utilizing a low pass filter to reduce the effect of noise and/or abrupt perturbations. For example, one or more received blood glucose measurements may each be replaced by a rolling average of the received blood glucose measurement and a predetermined number of prior blood glucose measurements.

The blood glucose measurements may be evaluated (229) by filtering for increasing blood glucose values and not filtering for decreasing blood glucose values. For example, a true blood glucose value may be used when it is less than a rolling average of blood glucose values. Blood glucose measurement may be evaluated at least in part by retaining a received blood glucose measurement that is less than a rolling average of a predetermined number of prior received blood glucose measurements and retaining the rolling average for the received blood glucose measurement otherwise. For example, a true CGM value may be used if it is less than a rolling average of the true CGM value and a predetermined number of prior CGM values, so decreasing BG values are accounted for immediately, but the rolling average may be used where the GM value is greater than the rolling average to avoid basing insulin dosing on localized blood glucose peaks. Peak filtering provides a double-sided safety on CGM values used for decision making by providing additional filtering/smoothing for increasing glucose values than for decreasing glucose values. Such double-sided safety can also be useful when determining or adjusting IOB, as will be described below, because if an actual IOB is lower than estimated, delivering insulin is safe; however, if an actual IOB is higher than estimated, no insulin will be delivered.

In some embodiment, the blood glucose measurements may also be evaluated (229) at least in part by projecting a downward trend of the received blood glucose measurements forward and adding the downward trend to the blood glucose measurement value used in the dose calculation. This may adjust for a long term downward trend over a period of hours in the fasting period (for example, this may be up to half the fasting period). The evaluating of the blood glucose measurement may also correct for basal drift. For example, when true BG values are trending downward over time (e.g., for 6 hours), the true blood glucose value may be adjusted downward based on and to reflect the forward projection of the downward trend, effectively reducing insulin dosing where BG is already drifting downward, protecting against inappropriate over-delivery of insulin and, thereby, guarding against inducing hypoglycemia. This provides correction for basal drift caused by incorrectly titrated basal insulin dosing, meal bolus dosing, and/or other physiological factors in that it compensates for (backs out) insulin effect to account for trend adjustments. However, adjusting for long-term drift during fasting period (164) may, in some

approaches, require determination of an appropriate slope of the drift to be compensated. One way in which this slope may be determined is through a linear regression analysis of a least mean squares fit for all or a subset of true, or evaluated, blood glucose measurements from the timeframe during which the drift slope is desired. Several additional ways to evaluate received blood glucose measurements are described in connection with Figures 3A to 3D.

IOB, target blood glucose, and/or one or more of the above-mentioned safety factors may be adjusted (230). For example, assumed IOB varies based on time elapsed from initialization of the delivery device and the duration of insulin action (DIA) so that the assumed IOB should, generally, decrease over fasting period (164). In some embodiments, correction dose calculating component (453) of delivery device (401) of Figure 4 may be configured to perform the functions of block (230).

An operating assumption is that assumed IOB is sufficient to bring initial blood glucose measurements back down to the blood glucose target over time. Accordingly, in some embodiments, if blood glucose measurements received within a predetermined interval of time after the start of fasting period (164) (or their evaluated proxies) rise, rather than fall, from their level during the initiation phase (when assumed IOB was initially set), assumed IOB may be recalculated and/or adjusted upwards based on the increased blood glucose measurement(s) and/or the evaluated proxy(ies) thereof. Such adjusting upward, or recalculating, of assumed IOB effectively reduces prospective insulin dosing where initial blood glucose measurements received during initialization phase underrepresented the actual upward trajectory of the blood glucose for which insulin may have already been administered during the prior non-fasting period utilizing the non-fasting modality. In some embodiments, IOB determining component (443) and/or assumed IOB component (444) of delivery device (401) of Figure 4 may be configured to perform one or more functions of block (230).

In some embodiments, target glucose levels may be adjusted (230) to be varied over time based at least in part on time elapsed from initialization of the delivery device. Accordingly, the target glucose level may be decreased over time during fasting period (164) (see, e.g., Figure 1C). In some embodiments, a rate at which the target glucose is decreased may be based at least in part on an assumption and expectation that glucose levels are currently being lowered by remaining assumed IOB.

The method may calculate (231) a correction dose by comparing an evaluated blood glucose measurement to a target blood glucose with the difference adjusted by the user ISF and a resultant dose compensated by the determined insulin on board. The method may limit or divide (232) the correction dose into portions with a maximum delivery rate for a maximum amount of

insulin to be delivered over a given time period. The given time period may be an interval at which blood glucose measurements are received. In some embodiments, correction dose limiting component (454) of delivery device (401) of Figure 4 may be configured to perform the functions of block (232). For example, the correction dose may be divided into portions (180a-180e) comprising up to a maximum amount of insulin to be delivered over a given time period. The method may then deliver (233) at least a portion of the correction dose, such as the divided portion. In some embodiments, dose delivery mechanism (431) of delivery device (401) of Figure 4 may be configured to perform the functions of block (233). For example, in reference to Figure 1C, correction dose (180a) may be delivered to the user by delivery device (130). If the correction dose is greater than the maximum per delivery period, correction dose (180a) may comprise just a portion of the calculated correction dose that is equal to the maximum per delivery period.

The method may continuously iterate (234) during the delivery stage (227) to accommodate periodically received blood glucose measurements. In one embodiment, a correction dose may be divided into a number of smaller portions to meet the maximum for delivery and one of the smaller portions may be given. When a next received blood glucose measurement is received, the method may determine whether to deliver the next divided portion or whether to adjust the dose based on an updated calculation.

The method may include an end procedure (235) to accommodate a fast-ending bolus as described above. By way of a use case example and not limitation, a user may wake with elevated glucose because the delivery of correction doses was conservative, operating under an assumption that the user would still sleep for several more hours, in which case, a final fast-ending correction bolus not associated with a meal (or a portion of such a correction dose comprising the remaining insulin in the delivery device) may be administered. By way of another, alternative use case example, such a final fast-ending correction bolus may be a hybrid corrective and meal bolus, administered at or near the end of the fasting period (164) to both correct waking elevated glucose and, further, in expectation of a meal being eaten during the subsequent non-fasting period (162) after the fasting period (164) has ended, for example as described in more detail in connection with Figures 5A to 5C.

Referring to Figure 2C, a flow diagram (240) shows another example embodiment of a method of controlling the delivery of insulin from a fasting-time wear delivery device, for example, such as the delivery device (130) of Figure 1A. A total daily basal dose information may be received (241) from a user during an initial setup of the delivery device, which may be used to estimate (242) an ISF for this user. Target blood glucose (BG) and insulin action time values may be fixed (243) for all users. The delivery device may detect (244) activation when the user starts to wear the device. The delivery device may accept (245) CGM BG data periodically, typically at 5 minute timepoints.

At the start of wear, when a first blood glucose value is received, a dose calculator may calculate (246) the dose that would have been required to correct the user to a target, and may immediately add this hypothetical dose to the IOB as an assumed IOB. The assumed IOB may be calculated by common methods known to those familiar with the art. This hypothetical dose is an assumed value of external insulin that might have been administered prior to activation of the delivery device. The first blood glucose value on which the assumed IOB is based may be averaged over a set of first blood glucose measurements and/or filtered to prevent an outlier value being used.

A next BG value that may have been processed or evaluated may be received (247) from a CGM and may be smoothed with a low pass filter to reduce the effect of noise and abrupt perturbations. When the BG values are trending downward over time, this downward trend may be projected forward (248) and added to the actual BG used in the dose calculator, effectively reducing insulin doses in cases of downward-drifting BG.

A dose calculator may be run (249) at each CGM timepoint to determine if insulin is required to bring the user to target. The basic calculator uses the equation (1):

$$(1) \quad \text{Dose_Calculation} = [(\text{Current_BG} - \text{Target_BG}) / \text{ISF}] - \text{IOB}$$

If the result is a positive number, the delivery device may deliver the corresponding sized dose, with the following limitation. A maximum dose given at any time point may be limited (250) to a small amount (for example 0.5 units) to further minimize sudden corrections. The dose may be limited by the hardware's resolution and smallest dose increment (for example, 0.1 units).

It may be determined (251) if a next BG value is received and, if so, the method may loop to repeat the filtering (247), trend evaluation (248), and dose calculation (249) and delivery (250). When it is determined (251) that there is no next BG value, the method may end (252).

Example correction dose calculating method

An example embodiment of a method of calculating the correction doses is described. This uses the equation (1):

$$(1) \quad \text{Dose_Calculation} = [(\text{Current_BG} - \text{Target_BG}) / \text{ISF}] - \text{IOB}$$

The Current_BG is a measured blood glucose value that may be evaluated before applying in the equation, for example, to filter for immediate readings or adjust for long term trends. The Target_BG is a user's target glucose level and may be set as a constant value for all users at the beginning of a fasting period.

Target glucose levels may be elevated by a safety factor compared to standard clinical

recommendations (for example, by raising the target by 5, 10, 20, 25% more than standard recommended 100-120 mg/dL (e.g., 130-180 mg/dL)). Target glucose levels may be optionally time varying based on time elapsed from initialization of the delivery device so that target glucose levels start elevated and decrease over the time of the wear period. The rate of decrease of target glucose levels may assume that glucose levels are being impacted (lowered) by external basal insulin injected or ingested during the time period proceeding wear of the delivery device.

A fixed glucose target means the method does not allow the user to modify the glucose target value. In one example, an additional 20 mg/dL safety margin above the typical 120 mg/dL BG target is implemented such that dose calculations are performed based on a 140 mg/dL fixed target to further safeguard against hypoglycemia. This additional safety margin helps account for expected BG variability due to sensor noise, basal drift, and dosing accuracy.

The ISF is how much one unit of insulin is expected to lower blood glucose of a specific user. This is based on a user-specific input that may be transmitted from an application or a user's smart pen. This may be learned over time when the delivery device is used repeatedly for fasting periods. ISF user-adapted parameter is the only user-adapted parameter available in the calculator. In some preferred embodiments, the ISF is biased toward less insulin delivery to reduce risk of hypoglycemia, e.g., safety factor (of 5, 10, 15, 20, 25%) may be applied, which, when used in a bolus calculator, results in more conservative calculation of insulin delivery amounts. In some embodiments, ISF may be initially set at a conservative default and/or predetermined value (e.g., a relatively high ISF that is biased toward lower insulin dosing) and adjusted and/or personalized over time, for example, based on a difference between actual or evaluated blood glucose measurements and expected blood glucose.

The ISF may be derived from total daily basal dose (TDBD) requested from the user or provided via an application or smart pen. Using a TDBD may reduce variability due to user error. For example, to remove the opportunity for significant ISF error due to incorrect estimation, the user may be prompted for their current TDBD amount (i.e. how much basal insulin they took over the last 24 hours), and ISF is estimated based on this input, rather than allowing it to be set manually. Generally, users are more likely to know this value and it is more likely to be accurate. Basing ISF on TDBD may reduce the probability that unsafe therapy parameters are entered into the calculator. A strong relationship exists between TDBD insulin use and ISF and, as appreciated by one skilled in the art, the following figures may be used: $ISF = 1700/TDD$ where TDD is total daily dose, and $TDBD = 0.47 \times TDD$, therefore $ISF = 800/TDBD$.

The assumed IOB is how much insulin is still active inside the body from previously externally received basal or bolus doses and this is subtracted from the correction dose. There are two types

of IOB in this calculator: assumed external IOB calculated as a hypothetical amount of externally administered insulin needed to correct the user's actual BG to a target BG; and delivered device IOB calculated based on insulin delivered by the current device as described herein.

IOB may be considered as the sum of two subtypes of IOB: (1) assumed IOB, which is an amount of externally administered insulin that would be needed to correct the user's actual initial BG to the Target_BG and that is assumed to have already been delivered to the user; and (2) delivered IOB, which is calculated based on insulin actually delivered to the user by the fasting period delivery device (130) as described herein. Since insulin is metabolized over time, IOB is adjusted over time based on known duration of insulin action (DIA). DIA is how long a bolus of insulin takes to finish lowering blood glucose. The DIA time starts when a bolus is given and ends when the bolus is no longer lowering blood glucose levels. An accurate DIA minimizes insulin stacking and low blood sugar (hypoglycemia), which can happen when boluses are given too close together.

According to equation (1) above, needed insulin yet to be delivered is ultimately determined based on a difference, between a representation of the user's actual real-time blood glucose levels (or sufficiently temporally recent, e.g., within 5 minutes) and a target blood glucose, that is then scaled according to a representation of the user's insulin sensitivity and further reduced by an amount of insulin that is calculated to already (or still) be active in the user's body. But a central focus of disclosed methods for calculating and/or controlling the delivery of one or more correction doses of insulin to a user during the fasting period is to guard against over-delivering, or calculating to over-deliver, insulin and to guard against the attendant hypoglycemia, especially because the user is expecting to be sleeping during a large portion of fasting period and will not be eating to provide any exogenous counter balance to an insulin overshoot into hypoglycemia. This makes effectively steering blood glucose toward a safe and healthy target in a suitable timeframe difficult because many unknown factors can affect a user's actual blood glucose levels and short-term dynamics. For example, user's short-term blood glucose readings can include fast, and sometimes aberrant, swings that do not always accurately reflect a long-term trend in the user's current blood glucose levels, or the amount of actual insulin on board still acting on those blood glucose levels. Compounding the difficulty, the user's insulin sensitivity can vary by time of day and, certainly, based on other physiological factors that are difficult to account for individually and directly including but not limited to stress (e.g., cortisol release).

Accordingly, methods for calculating and/or controlling the delivery of one or more correction doses of insulin to a user during the fasting period, and devices and/or systems configured to carry out such methods, solve various technical problems at least in part by utilizing a user's initial condition(s) (e.g., the user's initial blood glucose levels) to determine an amount of insulin that is

assumed to still be active in the user's system (assumed IOB) from the prior non-fasting period. This assumption of initial insulin sufficiency in the face of initially elevated blood glucose levels prevents insulin stacking at the beginning of the fasting period that would result from inappropriately dosing insulin in response to initially above-target blood glucose levels for which insulin has already been administered.

Moreover, insulin has a finite speed of action decreasing blood glucose levels. In other words, it takes a non-negligible period of time for delivered insulin to decrease blood glucose levels. Accordingly, even the most accurate current blood glucose levels are not necessarily accurate indicators of what actual blood glucose levels will be even a short period of time in the future without knowledge of actual insulin already on board for a particular user. And over time the body metabolizes insulin on board, decreasing its effectiveness at lowering blood glucose levels. Accordingly, even the most accurate current blood glucose levels and actual insulin on board are not necessarily accurate indicators of what actual blood glucose levels will be even a short period of time in the future without knowledge of actual determined insulin action (DIA) times for a particular user. For at least these reasons, utilizing the most accurate actual blood glucose levels at each time point (e.g., each CGM BG reading) may not necessarily best accomplish a goal of guarding against over-delivering insulin or guarding against calculating to over-deliver insulin. Rather, guarding against over-delivering insulin or guarding against calculating to over-deliver insulin may be better achieved by utilizing a processed, evaluated and/or filtered proxy of the user's actual blood glucose levels that more accurately represents the long-term trends of the user's actual blood glucose levels in a way that biases against the over-delivery of insulin, while also attenuating, eliminating or otherwise filtering out short-term noise and/or aberrations. Such processed, evaluated and/or filtered proxies of actual blood glucose may be called evaluated blood glucose herein.

Such methods, devices and/or systems also solve various technical problems at least in part by utilizing one or more safety factors to dynamically adjust (e.g., scale and/or translate) one or more of the variables utilized to determine insulin dosing (e.g., target blood glucose level, ISF and/or the assumed and/or delivered portions of IOB) to guard against over-delivering, or calculating to over-deliver, insulin and to guard against the attendant hypoglycemia.

The result of the above equation (1) is a correction dose which may be divided into smaller amounts in the form of delivery portions based on a maximum delivery rate. The maximum delivery rate over time is a maximum amount of insulin to be delivered over a determined time interval, with the amount in units of insulin, e.g., 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 units. The determined time interval may be a predetermined time interval, e.g., 5, 10, 15 minutes or may be based on intervals at which glucose data is being received. For example, no more than a

maximum dose amount may be delivered over 5 minutes when the dose calculation determines insulin should be delivered, after which the dose calculation is re-run (every 5-minutes or similar interval). A maximum dose amount may be calculated based on the maximum effect on a user over a predetermined time period e.g., 10 mg/dL decrease per 30 minutes. The maximum dose amount may be dependent upon the ISF calculation derived from the total daily basal amount.

In one example, only small insulin doses are given at each 5 minute interval to gradually reduce BG to target, making larger corrections as an “extended bolus dose”. Each dose is limited to a maximum insulin-lowering amount of 20 mg/dL based on the user’s ISF. For example, for a user with an ISF of 40 mg/dL per unit, the maximum insulin given per interval is limited to a maximum of 0.5 units. For example, if the dose calculation is 2 units, this may be divided into 4 using 0.5 unit increments. A first increment of 0.5 units may be delivered and when the next BG value arrives at the 5 minute mark, the dose calculator will know that 0.5 units has been delivered, and will continue delivering the next 0.5 units and so on unless the BG value changes such that the dose calculation requires adjustment.

The calculated correction delivery portions are delivered with a fixed zero basal rate as there is no basal delivered along with or otherwise by the described delivery device. This differs compared to known continuous-use pumps.

Blood glucose is measured in the user. This may come from a blood glucose monitor to the delivery algorithm via connectivity with an application and/or the cloud. Glucose levels are received periodically from a continuous glucose sensor, and may be processed with one or more of the following methods. Rapid measured actual BG increases may be filtered to reduce spikes. To reduce the likelihood of overdosing insulin based on sporadic CGM noise or localized BG fluctuations, a rolling average BG value may be used to filter increases in CGM values. The true CGM value may be used if it is less than the rolling average, so decreasing BG values are accounted for immediately, but increases are filtered to avoid dosing on localized peaks. Peak filtering provides a double-sided safety on CGM values used for decision making by providing additional filtering/smoothing for increasing glucose values but not for decreasing glucose values. Double-sided safety may be used because if an actual IOB is lower, delivering insulin is safe; however, if an actual IOB is higher, the method will not deliver insulin. Long term trends may also be adjusted to project downward trends many hours into the future (e.g., 6 hours). This provides correction for basal drift in that it compensates for (backs out) insulin effect for trend adjustment.

The method may provide safety factors or margins to any of the variables of the dose calculator, including target BG, IOB and/or may be applied as a separate adjustment to the dose calculation. A safety factor may be based on the user’s actual BG compared to a target BG, wherein the safety

margin is time varying. The safety margin may be applied once at the start of the session.

In one embodiment, a safety margin may be applied based on an assumption that the user has taken insulin from another source (referred to as external insulin) before application of the described delivery device and the taken insulin is sufficient to lower the current BG to the target BG at the outset of the user of the delivery device. An assumed external IOB is based on a hypothetical amount of external insulin needed to correct the user's hyperglycemia is based on a comparison of current BG to target BG such that:

$$[(\text{Current_BG} - \text{Target_BG}) / \text{ISF}] - \text{IOB} = 0$$

The assumed external IOB may be assumed from the equation above and not derived from known external insulin. The assumed IOB may have a time varying profile based on time elapsed from initialization of the delivery device based on duration of insulin action (DIA) so that the assumed IOB decreases over the time of wear period. As the assumed IOB drops, the dose calculation corrects down with the curve. The rate of decrease of expected glucose levels/IOB is based on an assumption that glucose levels are being impacted by external insulin injected or ingested during the time period proceeding initialization/wear of the delivery device.

Accounting for an assumed initial IOB sufficiency means the controller does not need to accept or use a known amount of external IOB info from the user. The correction dose calculation may be accomplished without external IOB input or knowledge. An initial assumed external IOB (referred to as "assumed IOB") calculated from $[(\text{Current_BG} - \text{Target_BG}) / \text{ISF}] - \text{assumed IOB}$ @ $t=0$ is simpler for the user and reduces user error.

Calculating a correction dose insulin delivery amount including the assumed external IOB being applied to the calculation is iteratively performed with each received actual BG value using the previous equation of:

$$\text{Dose_Calculation} = [(\text{Current_BG} - \text{Target_BG}) / \text{ISF}] - \text{IOB}$$

An assumed external IOB provides a safety margin and the IOB in the Dose_Calculation is equal to assumed external IOB + any active device IOB, with the active device IOB being the amount of insulin delivered since the beginning of use of the delivery device in the fasting period. The assumed external IOB may be decayed based on duration of insulin action (DIA). In this way, when the safety margin is embodied as an assumed external IOB that decays over time, any dose calculation over 0 (or a threshold such as 0.1 units of insulin) represents an unexpected BG, or incomplete external IOB, which is safely compensated for by delivering the difference (e.g., 0.1 unit insulin). DIA or active insulin time is how long a bolus of insulin takes to finish lowering blood glucose. The DIA time starts when a bolus is given and ends when the bolus is no longer lowering blood glucose levels. An accurate DIA minimizes insulin stacking and low blood sugar

(hypoglycemia), which can happen when boluses are given too close together.

In another implementation, the assumed external IOB is compared with actual duration of insulin action (DIA) calculated from actual BG or from the evaluated BG as described anywhere in this disclosure. In another implementation, the actual BG is compared with an expected BG calculated from DIA. These values and/or their comparisons may be used to create, calculate, determine, set, reset and/or select safety factors or margins. The values and/or comparisons may also be used to learn from the user's experience of previous safety margins in an effort to bias insulin dose calculation toward delivery of less insulin in the context of any unknowns that can affect blood glucose. A fixed setting for DIA may be used. This removes the opportunity for significant DIA error due to incorrect estimation. The pharmacokinetics/pharmacodynamics (PK/PD) of rapid acting insulin has been well-characterized as having a PK/PD peak at approximately 65 min, which correlates to a DIA of 6 hours. Accordingly, the DIA may be fixed at a value between about 5 and 7 hours because the delivery device only uses fast-acting insulin, preferably fixed at 6 hours. This may be combined with a fixed time constant (of about 60-70 minutes) for IOB calculation to avoid insulin stacking.

In some embodiments, ISF varies over time. For example, many people are more insulin resistant in the morning, making a lower ISF desirable in the morning portion of fasting period (164). Accordingly, in some embodiments, ISF may be set or reset based on the time of day. The ISF profile may use a learning algorithm configured to adjust the ISF based at least in part on histories of effective ISF, blood glucose measurements and/or blood glucose target(s) for the user during one or more prior fasting periods. In some embodiments, ISF may be initially set at a conservative default and/or predetermined value (e.g., a relatively high ISF) and adjusted/personalized over time based at least in part on comparisons between Actual and Expected BG trends/profiles in the context of correction doses that have already been delivered to the user during the fasting period.

The delivered insulin from the delivery device may be based on the calculated device correction amount with the delivery uninformed by actual external insulin on board. In this case, an initial delivery dose is zero because it is based on the assumption of the hypothetical situation of IOB sufficiency. The delivery delivers at least a portion, and typically a small portion of the calculated amount for safety. For example, if a 0.5 unit delivery portion per 5 minute interval is set, a 2 unit correction does will be split into 4 x 0.5 delivery portions. Notably, after 5 minutes, upon receiving a new glucose value, the calculation may be re-run and the ongoing correction delivery portion may be increased (more than 0.5 units) or decreased (fewer than 0.5 units).

Delivery may alternatively be a single correction dose; however, the delivery in smaller delivery

portions at a maximum delivery rate allows for slower correction and therefore safer correction, which is confirmed or updated with each iteration of a new actual BG being received.

As the described delivery device may be in the form of a fasting-time wear delivery device, the user will have used another therapy, such as MDI during the non-fasting time. For example, the delivery device may be worn at night with the user using MDI during the daytime. The use of MDI during the non-fasting time implies the existence of external IOB. Therefore, using a delivery device without the assumed IOB or without a known IOB, would be high risk as it would be uninformed by the external insulin amount. In other embodiments, the IOB may be known from the first therapy used during the non-fasting period and therefore the assumed external IOB calculation may not be required.

Description regarding ways in which blood glucose measurements may be evaluated, for example, according to block (229) in Figure 2B is continued below with reference to Figures 3A to 3D. Each of these may also be considered methods of implementing a safety factor that allows for biasing toward less insulin delivery in the context of any unknowns that may affect blood glucose values.

A method to determine such a slope for drift compensation is described in connection with Figure 3A, which illustrates a use case where a drift slope is to be determined for a plurality of true or evaluated blood glucose measurements in a timeframe (300). The evaluated blood glucose measurement is evaluated at least in part by projecting a downward trend of the received blood glucose measurements forward and adding the downward trend to the blood glucose measurement value used in the dose calculation. The downward trend is determined based at least in part on a largest negative slope between any received blood glucose measurement within a predetermined timeframe and a reference blood glucose measurement.

In some embodiments, timeframe (300) may comprise a portion of fasting period (164) of Figure 1C. In some embodiments, a predetermined timeframe (310) (e.g., occurring T_1 or more time before T_0 reference and T_2 or less time before T_0 , where $T_2 > T_1$) prior to a reference (e.g., most recent or last) blood glucose measurement (302) is established, for example, between T_1 to T_2 is 15 to 30 minutes or 30 to 60 minutes before reference measurement (302). A slope is determined for each straight line connecting one of the blood glucose values (303-306) within predetermined timeframe (310) with reference measurement (302), the largest slope is selected as representative of the drift over the timeframe (300), and an amount of downward adjustment is determined based on the selected slope and a length L of a prospective period during which the downward drift is to be extended (e.g., reference 302 reduced by an amount equal to the product thereof to evaluated value 301). Selecting the largest slope from glucose values a sufficient time

before reference measurement (302) solves a problem of underestimating blood glucose drift and, thereby overestimating insulin requirements, by preemptively adjusting true glucose values downward based on the fastest indication of long-term decline in blood glucose during the predetermined timeframe to account for future drift.

In some embodiments, evaluating received blood glucose measurements comprises filtering the received blood glucose measurements as described in connection with Figure 3B, which illustrates a use case where a drift slope is to be determined for a plurality of true or evaluated blood glucose measurements in a timeframe (320). The evaluated blood glucose measurement is evaluated at least in part by fitting received blood glucose measurements within a predetermined timeframe to a trend having a median slope selected from a plurality of regression fit slopes for different rolling subsets of received blood glucose measurements within the predetermined timeframe.

In some embodiments, timeframe (320) may comprise a portion of fasting period (164) of Figure 1C. In some embodiments, a linear regression fit slope, e.g., S_1 , is determined for all blood glucose measurements in a rolling window (322) of a predetermined interval (e.g., a 60-minute window from a first blood glucose measurement to a last blood glucose measurement in the window). Rolling window (322) is advanced by one or more blood glucose measurements and the linear regression fit slope, e.g., S_2 , S_3 , is redetermined for all blood glucose measurements in the advanced rolling window (322). Accordingly, for each blood glucose value rolling window (322) advances, one prior blood glucose value used in the prior regression fit will fall outside the back of the window and one next blood glucose value not yet used in the prior regression fit will enter the front of the window. In some embodiments, for each of those slopes (e.g., S_1 , S_2 , S_3) a rolling average may be determined by averaging the value of each slope and a predetermined number of prior, or immediately adjacent, slopes. This serves the function of smoothing out smaller variations in how quickly the slopes change (e.g., reduces volatility of the change). Then a median value (or other form of average) of the initial slopes (e.g., S_1 , S_2 , S_3), or of the rolling averages of each of those slopes, in timeframe (320) is selected (e.g., slope S_2) as representative of a trend for blood glucose values over timeframe (320), and the true blood glucose values (black dots) are filtered, or adjusted, to match the selected trend line extending from the first blood glucose value (321) of timeframe (320) (e.g., see white dots with black outline). Selecting the median slope (e.g., S_2) from among the regression fit slopes (e.g., S_1 , S_2 , S_3) of blood glucose values within rolling window (322), or in some cases from among the rolling averages of the regression fit slopes, ensures the value selected as indicative of the blood glucose trend over timeframe (320) is not driven by any extreme perturbation in either direction occurring within timeframe (320). This solves the problem of overdelivering insulin in the context of any unknown variables that may

affect blood glucose values by limiting the rate of change of glucose variations based on a moderate representative slope of received blood glucose values within a timeframe of interest.

In some embodiments, evaluating received blood glucose measurements comprises filtering the received blood glucose measurements as described in connection with Figure 3C, which illustrates a plurality of true and/or evaluated blood glucose measurements 903-909 from a recent timeframe (340) over which a blood glucose trend may be determined. A slope is determined for a line connecting each pair of neighboring glucose measurements, e.g., S_{2-3} , S_{3-4} , S_{4-5} , S_{5-6} , S_{6-7} , S_{7-8} , S_{8-9} . In some embodiments, a rolling average of those slopes may be determined by averaging the value of each slope and a predetermined number of prior, or immediately adjacent, slopes. This serves the function of smoothing out smaller variations in how quickly the glucose measurements change (e.g., reduces volatility of the change). Then a median value of the initial slopes, or of the rolling averaged slopes, in timeframe (340) is selected (e.g., slope S_{6-7}) as representative of a trend for blood glucose values over timeframe (340), and the true blood glucose values (342-349) (black dots) are filtered, or adjusted, to match the selected trend line extending from the first blood glucose value of timeframe (340) (e.g., see white dots with black outline). Selecting the median slope from among the individual slopes between adjacent true blood glucose values, or in some cases from among the rolling averages of the individual slopes between adjacent true blood glucose values glucose, may allow for representation of a trend in blood glucose over timeframe (340) that will better guard against over delivery of insulin while still effectively guiding the user's blood glucose toward a target range and then maintaining blood glucose near the target during fasting period (164). This solves the problem of overdelivering insulin in the context of any unknown variables that may affect blood glucose values by limiting the rate of change of glucose variations based on a moderate slope between adjacent received blood glucose values within a timeframe of interest.

In some embodiments, evaluating received blood glucose measurements comprises filtering the received blood glucose measurements as described in connection with Figure 3D, which illustrates a plurality of true or evaluated blood glucose measurements (363-368) from a recent timeframe (360) over which a blood glucose trend may be determined. The evaluated blood glucose measurement is evaluated at least in part by filtering the received blood glucose measurements, the filtering including: imposing a progressively increasing limit on how much each next received blood glucose measurement can increase compared to the previous received blood glucose measurement for increasing received blood glucose measurements; and amplifying how much each next received blood glucose measurement decreases compared to the previous received blood glucose measurement for decreasing received blood glucose measurements.

It is observed that blood glucose measurements (368, 367, 366) follow an increasing trend that then flattens out with measurement (365) and then begins to fall with measurements (364, 363, 362). In some embodiments, evaluation of true received blood glucose measurements comprises imposing a progressively increasing limit (e.g., L_1 , L_2 and L_3) on how much a next blood glucose value can increase compared to the previous value when the true blood glucose values are increasing (e.g., when the slope between adjacent true blood glucose values is positive, evaluation resulting in a deviation from true BG measurements shown for measurements (366 and 367) but amplifying a decrease (e.g., D_1 , D_2 , and D_3) between a blood glucose value and a next blood glucose value when the true blood glucose values are decreasing (e.g., when the slope between adjacent true blood glucose values is negative, evaluation resulting in a deviation from true BG measurements shown for measurements (362, 363 and 364). For example, while each true blood glucose value is greater than or equal to the prior one within timeframe (360), if a next true blood glucose value is more than a predetermined amount (e.g., L_1 , L_2 and L_3) greater than a prior evaluated blood glucose value, the next evaluated blood glucose value is set only the predetermined amount greater than the prior evaluated blood glucose value, the predetermined amount is increased and the evaluation is repeated for the next true blood glucose value. However, when the next true blood glucose value is less than the prior true blood glucose value, the next evaluated blood glucose value is set a multiple (e.g., any decimal value greater than one, 2x shown) of the difference (e.g., D_1 , D_2 , and D_3) between the next and prior true blood glucose values below the prior evaluated blood glucose value. This solves a problem of overdelivering insulin in the context of any unknown variables that may affect blood glucose values by allowing evaluated received blood glucose measurements to merge slowly with a rising CGM line that is rounding a taller and broader peak than would typically be smoothed by rolling averages of blood glucose measurements but to merge quickly with a falling CGM line, thereby allowing for representation of a trend in blood glucose over timeframe (360) that will better bias against over delivery of insulin while still effectively guiding the user's blood glucose toward a target range and then maintaining blood glucose near the target during fasting period (164).

The delivery algorithm of the method of controlling the delivery of insulin from a fasting-time wear delivery device (130) may be implemented as self-contained in the controller (132) of the delivery device (130) or using external processing for all or some of the delivery algorithm. For example, some of the evaluation of the blood glucose measurements may be carried out by the blood glucose monitor.

The controller (132) may be implemented in firmware that accepts GM blood glucose values (for example, via a BluetoothTM interface or other wireless communication. The delivery algorithm works in conjunction with a user's existing basal and meal bolus insulin, so unlike other pump systems, the fasting-time delivery device dispenses correction doses only. The delivery algorithm

uses a typical dose calculation, adjusting actual BG to target BG based on the user's ISF and IOB. The delivery algorithm includes safety mechanisms to reduce the chance of over-correction and subsequent hypoglycemia.

Referring to Figure 4, a block diagram shows an example embodiment of a system including a delivery device (401) with a controller (410), for example such as the described delivery device (130) with the controller (132) as shown in Figure 1A. The controller (410) may include a power source (433) and a recharging connector (434). The controller (410) may include a wireless communication module (413) for communication via a wireless network (405) with a continuous glucose monitor (GCM) (403) for receiving glucose measurement of a user. The controller (410) may also communicate via the wireless network (405) with a mobile computing device (402) such as a mobile phone, laptop or desktop computer. In some embodiments, mobile computing device (402) may correspond to mobile computing device (120) of Figure 1A. In some embodiments, glucose monitor (403) may correspond to CGM (105) of Figure 1A.

The controller (410) may include a microcontroller in the form of a processor (411) with firmware (412) that controls the operation of the delivery device (401). The firmware (412) may be provided by the components of the controller (410). The processor (411) may be a hardware module or a circuit for executing the functions of the described components which may be software units executing on the at least one processor (411). Memory may be configured to provide computer instructions to the processor (411) to carry out the functionality of the components.

The controller (410) may include a delivery component (420) that may be in communication with the mobile computing device (402) and/or the user glucose monitor (403) and determines when and how much to dispense in a dose by means of a dose delivery mechanism (431) of the delivery device (401) from a reservoir (432) of the delivery device (401). The delivery component (420) may include an initialization component (440) for an initial configuration stage of the delivery component (420) and a delivery stage component (450) for a delivery stage. The described components of the delivery component (420) may provide functionality corresponding to the medicament delivery methods described herein, in particular with reference to the steps of the flow diagrams of Figures 2A, 2B and 2C.

In some embodiments, controller (410) may also be configured to cause dose delivery mechanism (431) (or a similar separate mechanism of device (401) for glucagon) to deliver a predetermined and/or calculated amount of glucagon from a respective reservoir (similar to (432)) for glucagon based at least in part on blood glucose levels falling below a predetermined low level (e.g., 40mg/dl) and/or to maintain blood glucose levels above a predetermined safe level during episodes of intense user activity (e.g., exercise).

The initialization component (440) may include an activation component (446) for detecting activation of the delivery device to commence delivery of insulin. The initialization component (440) may include an insulin sensitivity factor (ISF) receiving component (441) for deriving an insulin sensitivity factor from a total daily basal dose information received from a non-fasting insulin management modality in a defined period prior to the fasting period for use in determining the correction bolus doses. The initialization component (440) may include a safety factor component (442) for providing safety factors to parameters on which the dose correction is based. The initialization component (440) may include an insulin on board determining component (443) including an assumed insulin on board component (444) for calculating an initial hypothetical correction bolus dose to correct an initial blood glucose measurement of the user to a target blood glucose and a device insulin on board component (445) for determining known delivered insulin from the delivery device.

The delivery stage component (450) may include a blood glucose measurement receiving component (451) for periodically receiving blood glucose measurements on which the correction bolus doses for a fasting period are based. The delivery stage component (450) may include a measurement evaluating component (452) for smoothing the received blood glucose measurements with a low pass filter to reduce the effect of noise or abrupt perturbations to obtain blood glucose values. The measurement evaluating component (452) may be for projecting received blood glucose measurements that are trending downward over time forward. The delivery stage component (450) may include a correction dose calculating component (453) for determining the correction bolus doses for a fasting period at each blood glucose measurement timepoint to determine when insulin is required to bring the user to a target blood glucose. The correction dose calculating component (453) compares a blood glucose value to a target blood glucose to obtain a difference that is adjusted by a user insulin sensitivity factor, wherein a dose blood glucose amount is compensated by a determined insulin on board. The delivery stage component (450) may include a correction dose limiting component (454) for limiting the correction bolus doses for a fasting period to a defined maximum dose given at any time point to minimize sudden corrections. The correction dose limiting component (454) may be for limiting the correction bolus doses for a fasting period to a minimum dose given at any time point based on the delivery device hardware. The delivery stage component (450) may include an end-procedure component (455) for coordinating an end bolus delivery at the end of the fasting period. The delivery stage component (450) may also include an end detecting component (456) for detecting an ending activity associated with ending the use of the insulin delivery device

Referring to Figure 5A, a flow diagram (500) shows an example embodiment of a method of using a delivery device for delivering insulin during a fasting period in the form of a wearable automated

insulin delivery (AID) device intended to be worn for the fasting period.

A user may use (501) a first therapy during a non-fasting period within an overall time period (such as a 24 hour period) to receive basal doses of insulin and bolus doses of insulin. The first therapy in the form of a non-fasting insulin management modality may include: a mode, method, device process, therapy, or the like that is used as an intervention in diabetes therapy. This may include a pump delivery of insulin, pen or syringe injection of insulin, inhaled insulin, oral insulin, or any form of insulin management used when the user is awake. The non-fasting insulin management modality may also include diet and exercise where insulin is managed, at least some of the time, without medicine intervention.

The user may use (510) a fasting insulin delivery device during a fasting period within the overall time period as an adjunctive therapy to the first therapy. The fasting insulin delivery device is an automatic insulin delivery device as described herein attachable to a user's body for the duration of the fasting period that delivers correction bolus doses in response to received blood glucose measurements and refrains from administering background basal doses. The user is not required to interact with the delivery device for correction of bolus insulin during the fasting period, which is typically when the user is asleep. The time period of intended fasting may be up to about 2 hours before the user goes to sleep and less than about 2 hours after waking.

In one embodiment, the user may fill (502) the fasting insulin delivery device with insulin before use during the fasting period. The filling may be carried out by using the insulin available from the first therapy. This enables a total insulin use to be monitored as the insulin is coming from a single source. Alternatively, the filling may be provided from a separate source, particularly if a different type of insulin is used in the delivery device compared to the first therapy. Filling may be carried out by inserting a pre-filled cartridge or a cartridge that is partially-filled from a previous use session. Filling may be carried out from a vial, syringe, pen or other insulin dosing apparatus.

The user may apply (503) the fasting insulin delivery device to their body for the fasting time period. The application may be immediately after a last meal of the non-fasting period or within a few hours. The user may apply the delivery device before bedtime or after finishing their daily meals. The delivery device may be applied to the body with adhesive to hold it in place and with needle/cannula sitting under skin. The user may determine when to apply and remove the delivery device based on personal day and night cycles. The duration and time in the day of the fasting period may vary from use to use by the same user. The user may be assisted in the use and application of the delivery device by a user application provided on a user's mobile computing device, for example, a smart phone. The user application may recommend when to apply/remove the delivery device. The user application may provide coordination with the first therapy.

The user may provide (504) insulin sensitivity information to set up the fasting insulin delivery device. This may be a once-off requirement when a user first uses the delivery device. This may be provided via the first therapy with or without user involvement. For example, a smart insulin pen may provide this information directly to the delivery device or via a user application. The insulin sensitivity information may be a total daily basal dose information as received from the first therapy in a preceding time period. For example, the user may provide their usual daily dose of basal insulin as provided by the first therapy. The insulin sensitivity information may be provided at least for a first use by a user of the delivery device where the delivery device includes a durable portion for repeated use during multiple fasting periods. The method may not allow the user to provide to the delivery device information relating to one or more of the following parameters: an amount of insulin to be delivered; a duration of insulin action; a target blood glucose; a basal rate (i.e., a rate of administration of, specifically, basal, background and/or baseline insulin required to maintain blood glucose at a target not including meal bolus doses); an IOB; and an insulin to carbohydrate ratio. The method may not allow the user to provide such parameters by not including any input means for the parameters to the delivery device.

The user may carry out (505) a starting activity associated with preparation of use of the insulin delivery device used during the fasting period. The user may receive insulin from the fasting insulin delivery device during a fasting period within the overall time period. The fasting insulin delivery device may be an automatic insulin delivery device attachable to a user's body for the duration of the fasting period. The user may receive (506) correction bolus doses in response to received blood glucose measurements without receiving any background basal doses from the fasting insulin delivery device.

The user may remove (507) the delivery device from their body at the end of the fasting period. Removing means stopping delivery of insulin via the delivery device by detaching it from the body. The removal may take place before or after an initial fast-ending meal. The user may remove the delivery device after or within about 2 hours of waking up. The user may remove the delivery device after determining an amount of additional insulin needed to cover the fast-breaking meal as described further in relation to Figure 5C.

The user may revert (508) to the first therapy when the fasting period ends and the delivery device has been removed from the user's body. However, it is not essential that the delivery device is removed before the first therapy is recommenced. The reservoir of the delivery device may only hold an amount of insulin needed for the fasting period and therefore this may be almost or completely empty. Also, any residual amount in the reservoir may be used by a fast-ending bolus or portion thereof.

In one embodiment, the fasting insulin delivery device is a wearable insulin reservoir pump that provides automated insulin delivery (AID) without user interaction and the first therapy is an insulin pen, which may be a smart pen. The pump may be configured to be filled by the insulin pen such that the delivered insulin comes from a single source and can therefore be accounted for.

The non-fasting insulin management modality and the fasting insulin delivery device may provide adjunctive use in the form of the supplemental use of one modality with another modality to provide therapy for a user. The fasting insulin delivery device may be used at regular or irregular intervals. For example, in a 24 hour period, a user may use the delivery device at regular sleep times, for example, 12, 10, 8, or 6 hours of sleeping time. However, other users may have a more erratic lifestyle and may require the fasting period to be at irregular times and for irregular periods of time.

The fasting insulin delivery device is personalized to the user and a delivery algorithm may learn from repeated use of the delivery device by the user. The delivery algorithm may learn one or more of: the ISF, DIA and may recommend the TDBD. The fasting insulin delivery device may provide correction bolus doses. Correction bolus doses during a fasting period are supplemental to meal boluses given during the non-fasting period, for example, when meal boluses have not sufficiently covered the rise in glucose resulting from a meal or when glucose remains elevated after meals or meal bolusing. This non-sufficiency may be due to errors in bolus calculation, errors in reported meal information, errors in therapy parameters used for therapy calculations, etc. The fasting period glucose control is achieved by a short-term wear insulin pump that provides AID control during fasting to allow the user to sleep well and wake in a target glucose range without awakening for correction bolusing. Daytime basal and daytime bolusing are accomplished by other types of therapy, such as MDI therapy.

The methods described solve the problem of transition complexity for transient use by providing a simplified system that allows for ease of transition between two different diabetes management modalities. In one implementation, the systems and methods described herein enable seamless, intermittent, episodic use of MDI during day cycles and AID during night cycles, thereby allowing users to benefit from low costs, high flexibility, and improved clinical outcomes. For example, diabetes management therapy with daily basal and daytime bolusing are accomplished by MDI therapy, while overnight glucose control is achieved by a short-term wear insulin pump that provides AID control during fasting to allow the user to sleep well and wake in a target glucose range without awakening for correction bolusing.

Referring to Figure 5B, a flow diagram (520) shows an example embodiment of a method of using

a delivery device for delivering insulin during a fasting period in the form of a wearable automated insulin delivery (AID) device worn for only the fasting period. The delivery device for delivering correction doses of insulin during a fasting period according to the described delivery method is a simple wearable insulin delivery device with limited user input or control due to safe guards and safety factors that are incorporated into the delivery algorithm. The delivery device only accepts and handles rapid-acting insulin for the correction doses.

The use of the delivery device is based on an assumption of daily basal and meal bolus insulin provided by an MDI therapy used (521) by the user during a non-fasting period prior to use of the delivery device. The MDI therapy may include external injection, ingestion or inhalation of insulin. In an example embodiment, the MDI therapy is provided by a smart insulin pen.

The user removes (522) the delivery device from a charger. As the delivery device is only used by the user during fasting periods, it can be charged during the non-fasting period, for example, during the daytime. The user may fill (523) a reservoir of the delivery device with an amount of insulin. In one embodiment, the user may fill (523) the reservoir using the MDI therapy device so that the amount of insulin added to the reservoir is known and accounted for in the MDI therapy. For example, a smart insulin pen may be used by the user to fill (523) the delivery device.

The user may apply (524) the delivery device to their body and activate the delivery device to prime it ready to start delivery of insulin correction doses according to the described delivery algorithm applied by the controller of the delivery device. The user may provide (525) information for an ISF that is provided to the controller of the delivery device, either directly or via a user application or cloud server. This may be provided at a time of a first of repeated uses of the delivery device, for example, when the delivery device is used each night. The ISF may be derived from a total daily basal dose (TDBD) requested from the user or provided via an application or smart pen.

The controller is configured to iteratively calculate correction doses of insulin based on the equation of: $\text{Correction_Dose} = [(\text{Current_BG} - \text{Target_BG})/\text{ISF}] - \text{IOB}$. The method is uninformed by other information from the user except for the information for the ISF. The method does not need, accept, or use other information from the following parameters or information: an amount of insulin to be delivered; a duration of insulin action; a target blood glucose; a basal rate; an IOB; an insulin to carbohydrate ratio. The delivery algorithm does not require the reservoir to be filled during use.

The user receives (526) correction doses from the delivery device during the fasting period. The user may optionally receive (527) a fast-ending dose to accommodate a fast-ending meal. The

fast-ending dose may be based on a remaining amount of the insulin in the reservoir. The user may remove (528) the delivery device from their body and return the delivery device to the charger. The correction doses are the only insulin delivered by the delivery device. No basal doses are given. The amount of insulin to be delivered by the delivery device cannot be modified by the user other than by removing the delivery device from their body. No more than a maximum dose amount is delivered over a defined interval (for example, 5 minutes) when the dose calculation determines insulin should be delivered.

The duration of insulin action (DIA or active insulin time) may be fixed and cannot be modified by the user. To remove the opportunity for significant DIA error due to incorrect estimation, a fixed setting is used. The target glucose may also be fixed and cannot be modified by the user and may have an additional safety factor. The IOB is assumed as described above based on an initial blood glucose reading and also determined by the delivery doses given by the delivery device. Insulin to carbohydrate ratio is not needed from the user as there is no meal bolus dose being delivered, with the exception of an optional fast-ending bolus. The insulin reservoir of the delivery device may be filled before wear and is not refilled during the wearing time. The delivery of insulin is totally automated except by removal of the wearable device, with no user control. Alerts or alarms are not required with the delivery device.

Referring to Figure 5C, a flow diagram (520) shows an example embodiment of a method of using a delivery device for delivering insulin during a fasting period in the form of a wearable automated insulin delivery (AID) device intended to be worn for a fasting period. The flow diagram (520) illustrates a fast ending procedure in which at least part of a fast-ending meal bolus may be provided from the remaining insulin in the reservoir of the delivery device.

The user may receive (541) correction bolus doses from the described delivery device during a fasting period. The user may provide (542) information at the end of the fasting period relating to a fast-breaking meal that requires a meal bolus. A meal bolus means an amount of insulin needed to compensate for an expected rise in glucose in a person with diabetes resulting from eating food. The compensation aims to bring the blood glucose into a target range. Typically, a user eating some amount of carbohydrates requires insulin to avoid resulting elevated glucose. Providing (542) information associated with the fast-breaking meal may include providing the information through user input via a connected insulin pen or from a user software application. The information may include meal information in the form of carbohydrates. The meal information may include glucose and IOB information.

An amount of bolus insulin recommended to cover the meal may be calculated based on the meal information, blood glucose data, and/or IOB information. The amount of insulin may be

determined by the delivery device dose calculator of the delivery device, by the first therapy method, or by a separate bolus calculator. When the user ends the fasting period in a target blood glucose range, the meal bolus calculation drives a delivery recommendation. When the user ends the fasting period with an elevated glucose, additional units may be recommended to cover the elevation.

The user may receive (543) at least part of the total recommended bolus from the delivery device. The amount received from the delivery device may be based on an amount of insulin available in the delivery device at the end of the fasting period. If the delivery device does not include the full total recommended bolus, the dose may be split.

The calculated recommended insulin bolus amount may be split into a first portion and second portion. Splitting means dividing a total recommended bolus amount into two distinct portions, which together add up to the total recommended bolus amount. The first portion may be determined based on the amount of insulin remaining in the insulin reservoir of the delivery device. This may be known, measured, or dispensed and then reported. This may include automatic delivery from the delivery device, with confirmation provided from a user application as described further in relation to Figure 7A or 7B. Alternatively, this may be by use of a control button on the delivery device to dispense remaining insulin up to a maximum required for the recommended insulin bolus amount. For example, if 4 units of insulin are left in reservoir of the delivery device, this is not wasted when removing the patch, rather the remainder can be delivered to the user. A second portion may be provided by another form of insulin therapy modality. This may be the first form of non-fasting therapy with the user currently at the beginning of the non-fasting period. The second portion is determined from a difference between the recommended bolus amount and the amount of bolus insulin remaining in the reservoir of the first modality. For example, if the meal bolus is 8 units, 4 units may be provided from a remainder in the reservoir, and 4 units may be delivered by insulin pen.

The user may receive (544) instructions to administer the second portion via the non-fasting therapy. Alternatively, this may be automatically sent to the therapy device, such as a smart insulin pen. Instructions to deliver the second portion with the first therapy may be delivered to the user via a connected device, such as the user smart insulin pen or via the user application. The IOB may also be sent to the user application or to the smart insulin pen for continuity of insulin delivery. This may be coordinated via the user application described further in relation to Figure 7A or via a separate therapy coordination user application described further in relation to Figure 7B. The user receives (545) any second portion from the non-fasting therapy and may remove (546) the delivery device, if not already removed.

Referring to Figures 6A to 6M, an example embodiment of a delivery device in the form of an AID delivery device (130) is shown in a series of illustrations of a user filling and application process. Figure 6A shows a packaging arrangement (600) of the delivery device and associated apparatus. A durable portion of the delivery device in the form of the controller (132) is provided with multiple sealed packages (605), for example, blister-packs, each containing a disposable dispensing unit (601). The dispensing units (601) each include a reservoir (602) and a plunger (603) supported on a base (606) with the plunger (603) provided for controlled delivery of insulin from the reservoir (602) to the user via a cannula. The controller (132) is attached to dispensing unit (133) to form the delivery device (130). In one arrangement, the dispensing units (601) may be provided with a coupler (604) attached and the dispensing units (601) may be provided without any insulin in their reservoirs (602) for filling from an MDI therapy pen or syringe by using the coupler (604) to position the pen or syringe. The packaging arrangement (600) may also include an applicator (135) and a charger (131) with a charging cable (608). Alternative embodiments may be configured to received pre-filled cartridges in place of the reservoir.

The dispensing unit (601) is provided in a sealed package (605) that is opened by the user to extract the dispensing unit (601) supported on the base (606) as shown in Figure 6B. The dispensing unit (601) may include a coupler (604) for attachment (611) of the insulin pen (110) as shown in Figure 6C to fill the reservoir (602). During filling of the reservoir (602) the plunger (603) is pushed backwards (612) as shown in Figure 6D. The plunger (603) may be colored to allow the user to see the movement of the plunger (603). The insulin pen (110) is removed (613) as shown in Figure 6E either together with or followed by the removal (614) of the coupler (604) as shown in Figure 6F to leave the dispensing unit (601). The controller (132) is attached (615) to the dispensing unit (601) to form the delivery device (130) as shown in Figure 6G.

A push applicator (135) is configured to attach (616) to an upper portion of the delivery device (130) as shown in Figure 6H to allow the delivery device to be removed (617) from the base (606) as shown in Figure 6I. The delivery device (130) held within the applicator (135) is positioned on the user's body as shown in Figure 6J. The applicator's push button (607) is pushed down (618) as shown in Figure 6K to exert a push force by the user via the applicator (135) to adhere the delivery device to the user's body by an adhesive attachment. The applicator (135) is removed (619) from the delivery device (130) as shown in Figure 6L and the delivery device (130) is then ready to deliver the correction doses during a fasting period. At the end of the fasting period, the delivery device (130) is removed from the user's body as shown in Figure 6M and returned (620) to the power charger (135).

The applicator (135) may surround and hold an upper portion of the delivery device such that the delivery device can be removed from the base (606) or positioned on the user's body with a single

hand. The push button (607) of the applicator (135) may cause a suitable force to detach the delivery device from the applicator (135) and push it onto the user's skin such that an adhesive surface on the underside of the delivery device attaches to the user's skin and a cannular on the underside of the delivery device pierces the user's skin ready for delivery of insulin.

Referring to Figure 7A, a flow diagram (700) shows an example embodiment of a method for managing delivery of insulin during a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period. The method is carried out by a computer software application provided at a mobile computing device, such as a smart phone or tablet. The computer software application may be an application for managing the described fasting period delivery device.

The method may register (701) a user of the application and may provide (702) training steps instructing the user how to use a delivery device including filling from an insulin pen. This may be carried out when a user first uses the delivery device. The method may request (703) user input of an insulin sensitivity factor or a total daily basal dose information in order to use this to set an ISF for the user. This may request a type of long-acting insulin used by the user and how many units of long-acting insulin is usually taken per 24 hours. The user may update this information, if this changes. To set up the delivery device for a fasting period, the method may pair (704) the mobile communication device running the application with a controller of the delivery device. The method may also pair (705) the mobile communication device running the application with a blood glucose monitor worn by the user. The pairing may be via a near field communication technology, for example, using Bluetooth™. The application may include instructions for pairing. The method may provide (706) the user's ISF to the delivery algorithm of the controller of the delivery device for use in the calculation of the correction doses.

During the fasting period (707), the method may receive (708) a record of blood glucose measurements as monitored from the glucose monitor and may send these to the controller for calculation of correction bolus doses. Alternatively, these may be sent directly from the glucose monitor to the controller. In another alternative, the glucose monitor may be integrated into the delivery device and provided within the controller. Filtering and projection of the blood glucose measurements may be carried out at the application in order to send evaluated blood glucose values to the controller for use in the delivery algorithm. The method may receive (709) a record of correction bolus doses given by the delivery device.

The method may include a fast-ending procedure in which the method receives (710) a fast-ending input from the user and may send this input to the delivery device controller. The method may receive (711) details from the controller of a fast-ending bolus dose. The method may notify

(712) the user of the end procedure with instructions to supplement the delivery device fast-ending dose with their insulin pen. The steps of (710) and (711) may be carried out during the fasting period (707) or at a time that the user breaks the fast. The method may provide (713) a session history including a display of correction doses given by the delivery device together with the blood glucose measurements and including additional statistics for user information. Session histories for previous sessions may also be provided.

Referring to Figure 7B, a flow diagram (720) shows an example embodiment of a method for managing delivery of insulin when using a fasting period from a delivery device in the form of a wearable automated insulin delivery device worn for the fasting period. The method is carried out by a computer software application provided at a mobile computing device, such as a smart phone or tablet. The computer software application may be a coordination application for coordination of the use of the fasting delivery device with a non-fasting insulin therapy, such as an MDI therapy using a smart insulin pen.

The method may register (721) a user of the application and may record user information relating to their insulin requirements. The method may receive (722) information relating to the non-fasting insulin therapy used by the user in an overall period. This may be received from the non-fasting therapy device, such as a smart insulin pen or an application governing the use of the non-fasting therapy device. Alternatively, this may be received from the user. The method may receive (723) information relating to the fasting delivery device delivering correction bolus doses within a fasting period of the overall period. This information may be received from the controller of the delivery device or from a separate application governing the user of the delivery device.

The method may provide coordination (724) between the non-fasting and fasting therapies and doses. The method may include providing recommendations (725) to the user. The coordination may include providing an ISF for the delivery device based on the use of the non-fasting therapy. The coordination may include providing an ISF at the end of the use of the delivery device. The coordination may provide additional parameter information for coordination between the therapies, including insulin on board at the time of transition between the therapies and basal drift.

The recommendations may include daily basal dose optimization to help the user tune their basal insulin in the non-fasting period. The recommendations may include indicating an amount of insulin to fill in delivery device for the fasting period. The recommendations may include whether and when to use the delivery device within an overall time period, including a timing of when to apply the delivery device in the overall time period. The recommendations may include an adjustment of a therapy or a therapy parameter.

The method may provide predictive outcomes (726) associated with an adjustment of a therapy or therapy parameters of the non-fasting therapy and the fasting delivery device (for example, an improved time in range), where the adjustment is represented by a hypothetical scenario. For example, a scenario may be predicted if the user wears the delivery device at night, between x and y hours what their blood glucose levels may be. Another example, may be if the user does not wear the delivery device for a night and the possible outcomes. A further example may be if the changes a daily basal amount from x to y, what the possible outcomes may be. In one embodiment, an implementation may be where a user's data can be uploaded and analyzed to determine the relative benefit of the described delivery device to an existing non-fasting therapy, for example, based on an increase time in range (TIR).

Figure 7C illustrates a use case with time extending vertically from top to bottom of the figure and interactions shown as horizontal lines with arrows extending between devices and/or entities involved in methods of insulin management for delivering insulin during fasting period (164) and/or coordination of such fasting period (164) insulin management with another therapy modality utilized during non-fasting period (162), in accordance with some example embodiments. Figure 7C illustrates a non-limiting, example use case including user (101), insulin pen (110), delivery device (130) and mobile device (120), as previously described in connection with Figure 1A or anywhere else in this disclosure. In a non-limiting example, user (101) may be a Type 1 diabetic, requiring consistent insulin therapy during both non-fasting periods (162) and during fasting periods (164).

As illustrated, user (101) is first operating non-fasting period (162), during which user (101) may self-administer a 24-hour slow-acting basal insulin dose (170a) and fast-acting meal bolus doses (172a-172d), for example, utilizing different insulin pens, e.g., insulin pen (110).

At some time during non-fasting period (162) the user may interact with mobile device (120), for example, running a coordination application for use of fasting delivery device (130) with a non-fasting insulin therapy to register the user (701, 721) with the app. Upon registration, the coordination app may be configured to provide user training steps (702) instructing the user how to use delivery device (130) including filling from insulin pen (110). The coordination app may then pair (704/705) (e.g., wireless communications pairing) with the controller of delivery device (130) and with the CGM (e.g., shown as integral with delivery device (130) but could also be a separate device). Once registration and pairing are complete, the coordination app may request (703) and the user may provide (706) ISF or TDBD to mobile device (120) for determination of ISF as described anywhere in this disclosure. Where it is determined rather than provided by the user, mobile device (120) may determine ISF as described anywhere herein and provide the ISF

to delivery device (130) (e.g., delivery device controller (132)).

The user may then perform a starting activity (201) as described anywhere in this disclosure. In some embodiments, this may include filling delivery device (130) with insulin as described in connection with at least Figures 6A-6M. Upon detection (201) of starting activity, delivery device (130) calculates and delivers correction doses (180a-180d) to the user (101) in response to actual and/or evaluated blood glucose values of the user during fasting period (164), for example as described anywhere in this disclosure.

At some point the user performs an ending activity (204) to signal a fast-ending procedure at the end of fasting period (164). Upon detection of this ending activity (204), the fast ending procedure may be entered. In some embodiments where the user's blood glucose is at target or within a target range after initiation of the fast ending procedure, no final correction dose (180e) may be delivered to the user. However, if the user's blood glucose is above target, e.g., for reasons as described anywhere in this disclosure, delivery device (130) may deliver a fast ending bolus (180e) to the user.

In yet other embodiments, the user intends to eat a meal at the beginning of the upcoming non-fasting period (162). In such embodiments, the user provides information (710) on the expected upcoming fast-breaking meal (e.g., carbohydrate information, etc.) to mobile device (120) and mobile device (120) provides such details to delivery device (130). Based on the meal information and current blood glucose levels, delivery device (130) determines a fast-breaking meal bolus and delivers it to the user as bolus (180e). As stated previously, in some cases the calculated fast-breaking meal bolus is larger than an amount of insulin remaining in delivery device (130). In such cases, bolus (180e) comprises the remainder of the insulin in delivery device (130) and then delivery device (130) sends, and mobile device (120) receives (711) details of fast-ending bolus (180e), which may include how much insulin is yet to be delivered via smart pen (110). The remainder of the calculated fast-breaking meal bolus is delivered manually, in non-fasting period (162), by the user via smart insulin pen (110). For example, mobile device (120) may notify (712) the user of an end procedure in which the user delivers the fast-ending bolus, in non-fasting period (162), via smart pen (110). In some embodiments, mobile device (120) may be configured to send instructions and/or dosing information for this fast-ending bolus to smart pen (110) such that smart pen (110) may be pre-set to deliver this fast-ending bolus.

Referring to Figure 8, a block diagram shows an example embodiment of a system including a mobile computing device (402) such as a mobile phone, laptop or desktop computer. The mobile computing device (402) may communicate via a wireless network (405) with a delivery device (401) such as the described delivery device (130). The mobile computing device (402) may also

communicate via the wireless network (405) with a continuous glucose monitor (GCM) (403) for receiving glucose measurement of a user. The mobile computing device (402) may include a wireless communication module (806).

The mobile computing device (402) may include a processor (802) for executing the functions of components described below, which may be provided by hardware or by software units executing on the mobile computing device (402). The software units may be stored in a memory component (804) and instructions may be provided to the processor (802) to carry out the functionality of the described components. In some cases, for example in a cloud computing implementation, software units arranged to manage and/or process data on behalf of the mobile computing device (402) may be provided remotely. Some or all of the components may be provided by a software application downloadable onto and executable on the mobile computing device (402).

A delivery device application (810) may be provided by the hardware or software units for managing the described fasting delivery device. The delivery device application (810) may include a registration component (811) for registering a user of the application and a user training component (812) for providing training steps instructing the user how to use a delivery device including filling from an insulin pen. The delivery device application (810) may include a basal insulin input component (813) for prompting and receiving a user input of a total daily basal dose information in order to use this to set an ISF for the user. The delivery device application (810) may include a controller pairing component (814) for pairing the mobile communication device (402) running the delivery device application (810) with a controller of the delivery device (401). The delivery device application (810) may include a glucose monitor pairing component (815) for pairing the mobile communication device (402) running the application (810) with a blood glucose monitor (403) worn by the user. The delivery device application (810) may include an ISF providing component (816) for providing the user's ISF to the delivery algorithm of the controller of the delivery device (401) for use in the calculation of the correction doses.

The delivery device application (810) may include a blood glucose providing component (817) for receiving blood glucose measurements as monitored from the glucose monitor (403) and sending these to the controller for calculation of correction bolus doses. The application (810) may include a dose calculating component (818) for carrying out one or more of the steps of calculating correction bolus doses, for example, as described anywhere in this disclosure. The dose calculating component (818) may function in coordination with the controller (310) of the delivery device (301). The dose calculating component (818) may function in coordination with a remote server. The application (810) may include a dose receiving component for receiving a record of correction bolus doses given by the delivery device.

The delivery device application (810) may include a fast-ending component (819) for providing a fast-ending procedure in which the delivery device application (810) receives a fast-ending input from the user and may send this input to the controller and may receive details from the controller of a fast-ending bolus dose in order to notify the user with instructions to supplement the delivery device fast-ending dose with their insulin pen or other therapy. The delivery device application (810) may include a session history component (820) for providing a session history including a display of correction doses given by the delivery device together with the blood glucose measurements and including additional statistics for user information. Session histories for previous sessions may also be provided.

A therapy coordination application (820) may be provided by the hardware or software units for managing the described fasting delivery device. The therapy coordination application (820) may be provided independently of the delivery device application (810). The therapy coordination application (820) may be combined with the or interact with the delivery device application (810). The therapy coordination application (820) may include a registration component (821) for registering a user of the application and may record user information relating to their insulin requirements. The therapy coordination application (820) may include a non-fasting therapy component (822) for receiving information relating to the non-fasting insulin therapy used by the user in an overall period. This may be received from the non-fasting therapy device, such as a smart insulin pen or an application governing the use of the non-fasting therapy device. Alternatively, this may be received from the user. The therapy coordination application (823) may include a delivery device therapy component (823) for receiving information relating to the fasting delivery device delivering correction bolus doses within a fasting period of the overall period. This information may be received from the controller of the delivery device or from the delivery device application (810).

The therapy coordination application (820) may include a coordination component (824) for providing coordination between the non-fasting and fasting therapies and doses. The therapy coordination application (820) may include a recommendation component (825) for providing recommendations to the user. The recommendations may include: a recommendation for the user to utilize the delivery device for a recommended timeframe at night; and a recommendation for the user to adjust daily basal doses of insulin from a current value to a different value. The therapy coordination application (820) may include a prediction component (826) for providing predictions to the user. The one or more predictions may include one or more of: a prediction of waking blood glucose levels for the user if the user utilizes the delivery device for the recommended timeframe at night; a prediction of waking blood glucose levels for the user if the user adjusts daily basal doses of insulin from a current value to the different value; and a

prediction of waking blood glucose levels for the user if the user does not utilize the delivery device for an entire night.

Figure 9 illustrates an example of a computing device (900) in which various aspects of the disclosure may be implemented. The computing device (900) may be embodied as any form of data processing device including a personal computing device (e.g. laptop or desktop computer), a server computer (which may be self-contained, physically distributed over a number of locations), a client computer, or a communication device, such as a mobile phone (e.g. cellular telephone), satellite phone, tablet computer, personal digital assistant or the like. Different embodiments of the computing device may dictate the inclusion or exclusion of various components or subsystems described below.

The computing device (900) may be suitable for storing and executing computer program code. The various participants and elements in the previously described system diagrams may use any suitable number of subsystems or components of the computing device (900) to facilitate the functions described herein. The computing device (900) may include subsystems or components interconnected via a communication infrastructure (905) (for example, a communications bus, a network, etc.). The computing device (900) may include one or more processors (910) and at least one memory component in the form of computer-readable media. The one or more processors (910) may include one or more of: CPUs, graphical processing units (GPUs), microprocessors, field programmable gate arrays (FPGAs), application specific integrated circuits (ASICs) and the like. In some configurations, a number of processors may be provided and may be arranged to carry out calculations simultaneously. In some implementations various subsystems or components of the computing device (900) may be distributed over a number of physical locations (e.g. in a distributed, cluster or cloud-based computing configuration) and appropriate software units may be arranged to manage and/or process data on behalf of remote devices.

The memory components may include system memory (915), which may include read only memory (ROM) and random access memory (RAM). A basic input/output system (BIOS) may be stored in ROM. System software may be stored in the system memory (915) including operating system software. The memory components may also include secondary memory (920). The secondary memory (920) may include a fixed disk (921), such as a hard disk drive, and, optionally, one or more storage interfaces (922) for interfacing with storage components (923), such as removable storage components (e.g. magnetic tape, optical disk, flash memory drive, external hard drive, removable memory chip, etc.), network attached storage components (e.g. NAS drives), remote storage components (e.g. cloud-based storage) or the like.

The computing device (900) may include an external communications interface (930) for operation of the computing device (900) in a networked environment enabling transfer of data between multiple computing devices (900) and/or the Internet. Data transferred via the external communications interface (930) may be in the form of signals, which may be electronic, electromagnetic, optical, radio, or other types of signal. The external communications interface (930) may enable communication of data between the computing device (900) and other computing devices including servers and external storage facilities. Web services may be accessible by and/or from the computing device (900) via the communications interface (930).

The external communications interface (930) may be configured for connection to wireless communication channels (e.g., a cellular telephone network, wireless local area network (e.g. using Wi-Fi™), satellite-phone network, Satellite Internet Network, etc.) and may include an associated wireless transfer element, such as an antenna and associated circuitry. The external communications interface (930) may include a subscriber identity module (SIM) in the form of an integrated circuit that stores an international mobile subscriber identity and the related key used to identify and authenticate a subscriber using the computing device (900). One or more subscriber identity modules may be removable from or embedded in the computing device (900).

The external communications interface (930) may further include a contactless element (950), which is typically implemented in the form of a semiconductor chip (or other data storage element) with an associated wireless transfer element, such as an antenna. The contactless element (950) may be associated with (e.g., embedded within) the computing device (900) and data or control instructions transmitted via a cellular network may be applied to the contactless element (950) by means of a contactless element interface (not shown). The contactless element interface may function to permit the exchange of data and/or control instructions between computing device circuitry (and hence the cellular network) and the contactless element (950). The contactless element (950) may be capable of transferring and receiving data using a near field communications capability (or near field communications medium) typically in accordance with a standardized protocol or data transfer mechanism (e.g., ISO 14443/NFC). Near field communications capability may include a short-range communications capability, such as radio-frequency identification (RFID), Bluetooth™, infra-red, or other data transfer capability that can be used to exchange data between the computing device (900) and an interrogation device. Thus, the computing device (900) may be capable of communicating and transferring data and/or control instructions via both a cellular network and near field communications capability.

The computer-readable media in the form of the various memory components may provide storage of computer-executable instructions, data structures, program modules, software units and other data. A computer program product may be provided by a computer-readable medium

having stored computer-readable program code executable by the central processor (910). A computer program product may be provided by a non-transient or non-transitory computer-readable medium, or may be provided via a signal or other transient or transitory means via the communications interface (930).

Interconnection via the communication infrastructure (905) allows the one or more processors (910) to communicate with each subsystem or component and to control the execution of instructions from the memory components, as well as the exchange of information between subsystems or components. Peripherals (such as printers, scanners, cameras, or the like) and input/output (I/O) devices (such as a mouse, touchpad, keyboard, microphone, touch-sensitive display, input buttons, speakers and the like) may couple to or be integrally formed with the computing device (900) either directly or via an I/O controller (935). One or more displays (945) (which may be touch-sensitive displays) may be coupled to or integrally formed with the computing device (900) via a display or video adapter (940).

The computing device (900) may include a geographical location element (955) which is arranged to determine the geographical location of the computing device (900). The geographical location element (955) may for example be implemented by way of a global positioning system (GPS), or similar, receiver module. In some implementations the geographical location element (955) may implement an indoor positioning system, using for example communication channels such as cellular telephone or Wi-Fi™ networks and/or beacons (e.g. Bluetooth™ Low Energy (BLE) beacons, iBeacons™, etc.) to determine or approximate the geographical location of the computing device (900). In some implementations, the geographical location element (955) may implement inertial navigation to track and determine the geographical location of the communication device using an initial set point and inertial measurement data.

Figures 10A to 10E are graphs that illustrate exemplary storylines of users using the fasting-time delivery method during a session of a fasting period, for example, overnight. The lines may represent either BG or IOB because one may be derived from the other. While the axis labels blood glucose (BG) as represented by the graphs, the lines may represent either BG or IOB (of course having different labels and values for IOB) because one may be derived from the other. Actual BG and Expected BG may be derived from Actual IOB and Assumed IOB and vice versa, as may be appreciated by a person skilled in the art.

Figure 10A is a graph (1010) that represents blood glucose over time during a fasting wear session. The solid line represents Actual BG trend/profile over time as measured by a CGM. The line of small dashes represents Expected BG trend/profile based on an Assumed External IOB profile over time as calculated at the start of the session based on assumed insulin sufficiency as

described above. The line of larger dashes represents device IOB calculated from insulin that the delivery device has delivered.

Figure 10B is a graph (1020) that represents blood glucose over time during a fasting wear session. The line of small dashes represents Actual BG trend/profile over time as measured by a CGM. The solid line represents Expected BG trend/profile based on Assumed External IOB. In this example of a wear session the Actual BG/IOB matches the Expected/Assumed BG/IOB so the assumption of external insulin sufficiency was true and no device insulin needed to be delivered. Notably, without the safety factors and/or biasing toward less insulin delivery in the context of any unknowns that may affect blood glucose values as described herein, especially calculation and utilization of assumed IOB, a device would have delivered insulin incorrectly at the start of session if uninformed by external insulin, which would have resulted in a dangerous overnight hypoglycemic event.

Figure 10C is a graph (1030) that represents blood glucose over time during a session. The solid line represents Actual BG trend/profile over time as measured by a CGM, showing an example of where actual glucose does not trend downward as expected, meaning the user likely did not take sufficient meal bolus at dinnertime or before applying the delivery device and starting the fasting period. The line of small dashes represents Expected BG trend/profile based on Assumed External IOB profile over time as calculated at start of the session based on assumed insulin sufficiency as described above. The vertical lines schematically represent the time period(s) during which insulin was delivered in small doses. Notably, although the Assumed External IOB was at a level that was not true to the actual, the algorithm was able to quickly learn that External IOB was not sufficient and was able to deliver correction insulin to ensure the user woke up in the target range.

Figure 10D is a graph (1040) that represents blood glucose over time during a session where the BG drops below expected overnight. The dashed line represents Actual BG trend/profile over time as measured by a CGM, showing an example of where actual glucose dropped downward unexpectedly toward hypoglycemia early during the session, meaning the user took too much meal bolus insulin at dinnertime or before applying the delivery device. The solid line represents Expected BG trend/profile based on Assumed External IOB profile over time as calculated at the start of the session based on assumed insulin sufficiency as described above. Notably, the delivery device did not deliver insulin at the start of the session despite being above target because of the implementation of a safety factor and/or biasing toward less insulin delivery in the context of any unknowns that may have affected blood glucose values as described herein. This use case also displays the benefit of upward adjustment to assumed IOB when initial blood glucose levels rise at the beginning of fasting period. By adjusting assumed IOB upward to

account for such an initial rise in blood glucose instead of dosing insulin, a potentially dangerous hypoglycemic event was further avoided.. If insulin had been delivered responsive to the initial glucose being higher than a standard clinical target, the result would have been an even more severe overnight hypoglycemic event.

Figure 10E is a graph (1050) that represents blood glucose over time during a session illustrating a session wherein Actual BG rises slowly towards end of session (e.g., dawn effect). The solid line represents Actual BG trend/profile over time as measured by a CGM, showing an example of where the actual glucose rose upward toward the end of the session (dawn effect), which could be caused by external basal insulin or other physiological factors. The vertical lines generally represent time period(s) during which correction doses of insulin were delivered by the delivery device dose calculation. Notably, because the safety margin decreases over time based on the assumption reduction in likelihood of external insulin, the delivery device delivered sufficient insulin to reduce the “dawn effect” otherwise experienced by some MDI users. Advantageously, the delivery algorithm allows for daytime MDI diabetes management users to benefit from nighttime continuous AID wear, increasing time in range without increasing hypoglycemia risk.

GLUCAGON DELIVERY EMBODIMENTS

The above description and embodiments are focused on insulin management during a fasting period. However, the delivery device and associated methods and systems may alternatively or additionally be used with any other medicament affecting blood glucose levels. An embodiment is described in which the medicament is glucagon for increasing blood glucose concentrations when they fall below predetermined levels, for example, during sleep, or athletic or otherwise energetically demanding physical activity. The description of aspects and features of the embodiments provided for the insulin delivery device may be used equivalently for a glucagon delivery device.

Figure 11A shows a block diagram (1100) of an example embodiment of a delivery device (1101) for use with glucagon and an associated mobile computing device (1102) for use in example coordination with the delivery device (1101). A wireless communication network (1105) may be used for communication between the delivery device (1101), the mobile computing device (1102), a glucose monitor (1103), and optionally a remote server. Delivery device (1101) may be utilized at any time of day or night. Delivery device (1101) is configured to deliver glucagon in one or more small correction doses based at least in part on periodic blood glucose measurement from a glucose monitor (1103). In some embodiments, CGM may be incorporated into delivery device (1101). In other embodiments, CGM may be a separate CGM worn by the user day and night. The delivery device (1101) may comprise a durable unit into which a disposable dispensing unit containing the glucagon is fitted. Delivery device (1101) may have an applicator (not shown but

similar to applicator (235)) for use while filling delivery device (1101) with glucagon and/or for applying delivery device (1101) to the user's body, for example as described for the insulin delivery device (130) anywhere in this disclosure.

The durable unit of delivery device (1101) includes a controller for controlling the delivery of glucagon from delivery device (1101) according to a delivery algorithm by a delivery component (1120). The delivery algorithm may be provided entirely on controller. This may be provided in the form of software and/or hardware components. In a first alternative, the delivery algorithm may be provided remotely instructing the delivery amounts to the controller. This may be provided remotely from: cloud computing system; computer application (1110) on user's mobile computing device (1102); or another form of computing device or system. In a second alternative, the delivery algorithm may be distributed between any two or more of: the controller; cloud computing system; computer application on a user's mobile computing device; and another form of computing device or system. Controller may include a delivery component (1120) that may be in communication with mobile computing device (1102) and/or glucose monitor (1103) and determines when and how much to dispense in a dose by means of a dose delivery mechanism of delivery device (1101) from a reservoir of the delivery device (1101). Delivery component (1120) may include an initialization component (1140) for an initial configuration stage of the delivery component (1120) and a delivery stage component (1150) for a delivery stage.

In some embodiments, controller may also be configured to cause dose delivery mechanism to deliver a predetermined and/or calculated amount of glucagon from reservoir based at least in part on blood glucose levels falling below a predetermined low level (e.g., 40mg/dl, 50mg/dl, 60mg/dl, 70mg/dl) and/or to maintain blood glucose levels above a predetermined safe level (e.g., 60mg/dl, 70mg/dl, 80mg/dl) during episodes of intense user activity (e.g., exercise).

Initialization component (1140) may include an activation component (1146) for detecting activation of the delivery device to commence delivery of glucagon as described anywhere in this disclosure. In some but not all embodiments, initialization component (1140) may include a glucagon sensitivity factor (GSF) component (1141) for receiving a glucagon sensitivity factor from the user or from a doctor and/or for deriving or otherwise determining a glucagon sensitivity factor from one or more other parameters. For example, in some embodiments, default amounts of glucagon may be based on a doctor's prescription, input by a user, or may be based on the user's age and/or weight from a look up table. In embodiments where a GSF is utilized, GSF component (1141) may be configured to determine, adjust and/or adapt GSF, or an effective GSF, based on one or more of a variety of factors, including but not limited to prior and/or current blood glucose values, IOB, patient history, knowledge of whether the user is awake and/or aware of the event, e.g., via interaction with a UI of mobile device (1102). Initialization component (1140) may

include a safety factor component (1142) for providing one or more safety factors to parameters on which dose correction is based as described anywhere in this disclosure, for example, evaluating blood glucose values and/or target blood glucose as described anywhere in this disclosure.

Delivery stage component (1150) may include a blood glucose (BG) measurement receiving component (1151) for periodically receiving blood glucose measurements on which correction bolus doses of glucagon are based. Delivery stage component (1150) may include a measurement evaluating component (1152) for smoothing, manipulating, modifying and/or supplementing the received blood glucose measurements to reduce the effect of noise or abrupt perturbations on obtained blood glucose values as described anywhere in this disclosure. In some embodiments, such smoothing, manipulating, modifying and/or supplementing the received blood glucose measurements may also be considered implementing a safety factor on the received blood glucose measurements in order to avoid overdosing over or underdosing glucagon.

Delivery stage component (1150) may include a correction dose determining component (1153) for determining whether a glucagon correction bolus dose is appropriate based on one or more true and/or evaluated blood glucose measurements to bring the user to a target blood glucose (or above such a target value). Correction dose determining component (1153) may be configured to compare a received blood glucose value from measurement receiving component (1151) (or a smoothed, manipulated, modified and/or supplemented value from evaluating component (1152)) to a target blood glucose. In some embodiments, correction dose determining component (1153) is configured to make an affirmative determination to deliver a predetermined correction dose of glucagon (e.g., 1mL) calculated to increase the user's blood glucose level above the target blood glucose level based on one or more factors. Such factors may comprise the received and/or evaluated blood glucose value first falling below the target blood glucose. Such factors may comprise the received and/or evaluated blood glucose value staying below the target blood glucose for one or more consecutive iteration periods of received and/or evaluated blood glucose values, or for a predetermined interval of time. Such factors may comprise the received and/or evaluated blood glucose value being below the target blood glucose and a first derivative (rate of change) of the received and/or evaluated blood glucose values are below a predetermined value (e.g., 0), e.g., indicating blood glucose levels are below the target and are not increasing or are not increasing fast enough. Such factors may comprise the received and/or evaluated blood glucose value being below the target blood glucose and a second derivative (acceleration of change) of the received and/or evaluated blood glucose values are below a predetermined value (e.g., 0), e.g., indicating blood glucose levels are below the target and are not increasing fast enough. In some but not all embodiments, where a glucagon sensitivity factor (GSF) is utilized in

determining a size of a correction dose of glucagon to be delivered, amounts of delivered glucagon may be based on a doctor's prescription, input by a user, or may be based on the user's age and/or weight from a look up table (as described above). In some such embodiments, correction dose determining component (1153) may also, or alternatively, be configured to determine, adjust and/or adapt GSF, or the effective GSF, based on one or more of a variety of factors, including but not limited to prior and/or current blood glucose values, IOB, patient history, knowledge of whether the user is awake and/or aware of the event, e.g., via interaction with a UI of a mobile device (1102).

Delivery stage component (1150) may include an alarm component (1154) configured to trigger an alarm or send, or cause to be sent, an indication to another mobile device (e.g., (1102)) that the blood glucose levels of the user of delivery device (1101) have triggered the target blood glucose (e.g., has fallen below the target). In some embodiments, such a mobile device may be monitored by a caregiver, such as a doctor or a parent of a child using the glucagon delivery device, thereby allowing the caregiver to be notified of developments regarding the user's blood glucose and care.

The mobile computing device (1102) may communicate via wireless network (1105) with delivery device (1101) and may include a wireless communication module (1163). Mobile computing device (1102) may also include a user interface (1164) configured to display any indications and/or information to the user and/or receive any information from the user as required, desired and/or described anywhere in this disclosure. In some embodiments, one or more portions or functionalities of the processing of controller of the delivery device including the delivery algorithm may be provided remotely by the mobile computing device (1102). In other embodiments, one or more portions or functionalities of the processing of controller including the delivery algorithm may be provided remotely by a cloud server either directly to the controller or in coordination with the mobile computing device.

A delivery device application (1110) of the mobile computing device (1102) may be provided by the hardware or software units for managing the described fasting delivery device as described anywhere in this disclosure. Delivery device application (1110) may include a registration component (1111) for registering a user of the application as described anywhere in this disclosure. Delivery device application (1110) may include a user training component (1112) for providing training steps instructing the user how to use a delivery device as described anywhere in this disclosure, including filling glucagon. Delivery device application (1110) may include a controller pairing component (1114) for pairing mobile communication device (1102) running delivery device application (1110) with a controller of delivery device (1101). Delivery device application (1110) may include a glucose monitor pairing component (1113) for pairing mobile

communication device (1102) running application (1110) with blood glucose monitor (1103) worn by the user.

In some embodiments, delivery device application (1110) may include a glucagon sensitivity factor (GSF) providing component (1117) for providing the user's GSF to the delivery algorithm of the controller of the delivery device (1101) for use in the calculation of the correction doses as described anywhere in this disclosure. In some embodiments, glucagon delivery is not determined based on a GSF of the user, instead being a predetermined dose for all users, a predetermined dose based on age and/or body size of the user, or a dose determined or predetermined according to any other suitable metric(s). Delivery device application (1110) may include a blood glucose providing component (1115) for receiving blood glucose measurements as monitored from glucose monitor and sending these to the controller for calculation of correction bolus doses as described anywhere in this disclosure. In some embodiments, application (1110) may include a dose receiving component (1116) for receiving a record of glucagon correction bolus doses given by the delivery device as described anywhere in this disclosure.

Delivery device application (1110) may include a session history component (1118) for providing a session history including a display of glucagon correction doses given by the delivery device together with the blood glucose measurements and, in some cases, including additional statistics for user information as described anywhere in this disclosure. For example, as previously described, session history component (1118) may be configured to provide an indication that the blood glucose levels of the user of delivery device (1101) have triggered the target blood glucose (e.g., has fallen below the target). In some such embodiments, mobile device (or any other electronic device configured to receive such an indication) may be monitored by a caregiver, such as a doctor or a parent of a child using glucagon delivery device (1101), thereby allowing the caregiver to be notified of developments regarding the user's blood glucose and care. Session histories for previous sessions may also be provided as described anywhere in this disclosure.

Referring to Figure 11B, a flow diagram (1170) shows an example embodiment of a method of controlling the delivery of glucagon from a delivery device, for example, delivery device (1101) of Figure 11A. The method may be utilized to deliver glucagon at any time of day or night from delivery device (1101). In some embodiments, no insulin is given by delivery device (1101). Such a method may be carried out at and/or by a controller at and/or by delivery device or mobile computing device, and/or remotely at and/or by a server, computing device, or the like, instructions then being sent to the controller. In some embodiments, certain steps may be carried out by such an above-described controller of the delivery device and/or with some of the steps carried out remotely to the controller. Accordingly, in some embodiments, such methods may be carried out in cooperation with such an above-described controller with a user application

provided on a user's mobile computing device, for example mobile computing device.

While not shown in flowchart (1170), such a method may include delivery device (1101) detecting its own activation, for example and not limitation, when the user starts to wear device (1101). Alternatively, where one or more steps and/or calculation procedures are carried out remotely by another device, such as mobile device or remote cloud device, such a method may include detection or receiving notification, by the other device, of such activation of delivery device (1101).

The method may include an initialization stage (1172) in which various parameters and safety factors are set-up for the delivery algorithm, and a delivery stage (1180) in which correction dose(s) are calculated and/or delivered to the user. In some embodiments, some steps, or safety factors, of the initialization stage (1172) may be updated during the delivery stage (1180).

Block (1173) includes receiving a first blood glucose measurement. For example, blood glucose measurements may be received periodically from a glucose monitor. Block (1174) includes setting the blood glucose target. For example, as stated above, target blood glucose may be set at a relatively low level (e.g., 40mg/dl, 50mg/dl, 60mg/dl, 70mg/dl) to guard against severe hypoglycemia. In some embodiments, target blood glucose may be set a predetermined or constant value for all users, or at a respective one of a plurality of constant values for each of a plurality of classifications of user. As previously described, safety factors may also be applied to actual blood glucose measurements in the form of filtering and/or any other modification thereto as described anywhere in this disclosure. However, such adjustments are largely discussed as evaluating blood glucose measurements at block (1182).

During the delivery stage (1180), at block (1181), blood glucose measurements are periodically received, for example, from a glucose monitor. As stated above, guarding against over-delivering, or calculating to over-deliver, glucagon may be better achieved by utilizing a processed, evaluated and/or filtered proxy of the user's actual blood glucose levels that more accurately represents the long-term trends of the user's actual blood glucose levels while also attenuating, eliminating or otherwise filtering out short-term noise and/or aberrations. Accordingly, at block (1182), the periodically received blood glucose measurements (or a subset thereof) are evaluated. For example, the periodically received blood glucose measurements may be processed and/or filtered as described anywhere in this disclosure in order to obtain a proxy of the user's actual blood glucose levels that more accurately represents the long-term trends of the user's actual blood glucose levels while also attenuating, eliminating or otherwise filtering out short-term noise and/or aberrations. While such evaluation may be carried out by delivery device (1101), mobile device (1102) and/or computing device, in some embodiments, such evaluation of blood glucose measurements as described anywhere in this disclosure, or portions thereof, may be carried out

by CGM (1103).

At block (1183), a need for glucagon delivery is determined based on evaluated blood glucose measurements and target blood glucose and based on one or more factors. Such factors may comprise the received and/or evaluated blood glucose value first falling below the target blood glucose. Such factors may comprise the received and/or evaluated blood glucose value staying below the target blood glucose for one or more consecutive iteration periods of received and/or evaluated blood glucose values, or for a predetermined interval of time. Such factors may comprise the received and/or evaluated blood glucose value being below the target blood glucose and a first derivative (velocity of change) of the received and/or evaluated blood glucose values are below a predetermined value (e.g., 0), e.g., indicating blood glucose levels are below the target and are not increasing or are not increasing fast enough. Such factors may comprise the received and/or evaluated blood glucose value being below the target blood glucose and a second derivative (acceleration of change) of the received and/or evaluated blood glucose values are below a predetermined value (e.g., 0), e.g., indicating blood glucose levels are below the target, are not increasing fast enough, and/or the increase in blood glucose levels is not increasing fast enough.

Block (1184) comprises delivering one or more correction glucagon doses. For example, in reference to Figure 11C, a graph (1190) shows blood glucose over time and one or more glucagon doses (1191) that may be delivered to the user by delivery device (1101) upon blood glucose falling below the target value shown in a dotted line. As illustrated, blood glucose begins to rise after delivery of the one or more glucagon doses (1191) and quickly reaches a level above the target. For example, in some embodiments, if subsequent blood glucose measurements after delivering an initial glucagon dose reveal that blood glucose levels are still under the target and not rising (e.g., first derivative of blood glucose measurement values is zero or negative), or are under the target and not rising fast enough (e.g., second derivative of blood glucose measurements values is not sufficiently large in relation to the first derivative to predict blood glucose levels will rise above the target within a predetermined interval of time (e.g., 15 minutes)) one or more subsequent doses of glucagon may have been delivered.

In some embodiments, the size of the glucagon dose(s) may be determined based on age and/or bodyweight of the user. For example, for powder or solution injections, individuals 6 years and older and weighing 25kg or more may receive 1mL of glucagon injection, while individuals under 6 years old or weighing less than 25kg may receive 0.5mL of glucagon injection. In further example, for autoinjector or prefilled syringes, individuals 12 years and older may receive 1 mg or 0.2mL of glucagon injection, children 2 to 11 years old and weighing 45kg or more may receive 1 mg or 0.2mL of glucagon injection, children 2 to 11 years old and weighing less than 45kg may

receive 0.5 mg or 0.1mL of glucagon injection, and children under 2 years may receive a doctor determined dose of glucagon injection. In some embodiments, where multiple glucagon doses are delivered, appropriate above-mentioned glucagon dose may be divided into several smaller, micro-doses, for example as shown in Figure 11C.

Block (1185) comprises continuously iterating for the next blood glucose measurement during the delivery stage (1180) to accommodate periodically received blood glucose measurements. When a next received blood glucose measurement is received, the method may include determining whether to deliver another glucagon dose based on an updated calculation, thereby, providing a correction to avoid severe hypoglycemia risk.

A use case for glucagon delivery, for example via delivery device (1101), will now be described. In a first use case, a 9 year old, 30kg type 1 diabetic girl is attending a sleepover and a friend's house and the girl's parents are concerned about whether she will be able to properly control her blood sugar, especially without their parental supervision. During the early evening, the girl's blood glucose is generally maintained within a range of 100-150mg/dL. However, once the child has fallen asleep, for any number of reasons including but not limited to overdosing meal bolus insulin or basal insulin during the day, her blood glucose begins to drift downward, for example as shown in Figure 11C. At some time during the night, when the child is sleeping, her blood glucose falls below the target, which may be 40mg/dl in an example. Since such a lower blood glucose level can interfere with the brain's ability to take up blood glucose for energy, a dangerous hypoglycemic event is occurring. Based on blood glucose values being below the target, delivery device (1101) delivers a 0.5 mg or 0.1mL of glucagon dose to the girl, and her blood glucose levels quickly rise above the target and into safer territory for her context, sleeping or resting. In some such embodiments, delivery device (1101) delivers the above glucagon dose as a series of micro-doses that, together, total the desired 0.5 mg or 0.1mL of glucagon dose. In some embodiments, delivery device (1101) sends an alarm message to a mobile device running an application for remote monitoring of the child's blood glucose levels and/or operation of delivery device (1101), for example, providing indication of the hypoglycemic event and/or particulars of the relevant session history to the parent.

Another use case for glucagon delivery, for example via delivery device (1101), will now be described. In a first use case, a 12 year old, 46kg type 1 diabetic boy is attending an afternoon sporting event and the boy's parents are concerned about whether he will be able to properly control his blood sugar, especially during high levels of physical activity. During the sporting event, the boy's blood glucose is generally maintained within a range of 80-120mg/dL. However, during a particularly physically demanding interval, his blood glucose begins to drift downward, for example as shown in Figure 11C. At some time during the particularly physically demanding

interval, his blood glucose falls below the target, which may be 60mg/dl in this example, although any other suitable blood glucose target is also contemplated. Since such a low blood glucose level can interfere with muscle's ability to fire maximally and the brain's ability to function effectively and control those muscles, a dangerous hypoglycemic event is occurring. Based on blood glucose values being below the target, delivery device (1101) delivers a 1 mg or 0.2mL of glucagon dose to the boy, and his blood glucose levels quickly rise above the target and into safer territory for the context of his situation, waking physical exercise. In some such embodiments, delivery device (1101) delivers the above appropriate glucagon dose as a series of micro-doses that, together, total the desired 1 mg or 0.2mL of glucagon dose.

The foregoing description has been presented for the purpose of illustration; it is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Persons skilled in the relevant art can appreciate that many modifications and variations are possible in light of the above disclosure.

Any of the steps, operations, components or processes described herein may be performed or implemented with one or more hardware or software units, alone or in combination with other devices. In one embodiment, a software unit is implemented with a computer program product comprising a non-transient or non-transitory computer-readable medium containing computer program code, which can be executed by a processor for performing any or all of the steps, operations, or processes described. Software units or functions described in this application may be implemented as computer program code using any suitable computer language such as, for example, Java™, C++, or Perl™ using, for example, conventional or object-oriented techniques. The computer program code may be stored as a series of instructions, or commands on a non-transitory computer-readable medium, such as a random access memory (RAM), a read-only memory (ROM), a magnetic medium such as a hard-drive, or an optical medium such as a CD-ROM. Any such computer-readable medium may also reside on or within a single computational apparatus, and may be present on or within different computational apparatuses within a system or network.

Flowchart illustrations and block diagrams of methods, systems, and computer program products according to embodiments are used herein. Each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, may provide functions which may be implemented by computer readable program instructions. In some alternative implementations, the functions identified by the blocks may take place in a different order to that shown in the flowchart illustrations.

A computer program product may include one or more computer readable hardware storage devices having computer readable program code stored therein, said program code executable by one or more processors to implement the described methods.

Some portions of this description describe the embodiments of the invention in terms of algorithms and symbolic representations of operations on information. These algorithmic descriptions and representations, such as accompanying flow diagrams, are commonly used by those skilled in the data processing arts to convey the substance of their work effectively to others skilled in the art. These operations, while described functionally, computationally, or logically, are understood to be implemented by computer programs or equivalent electrical circuits, microcode, or the like. The described operations may be embodied in software, firmware, hardware, or any combinations thereof.

The language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the invention be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments of the invention is intended to be illustrative, but not limiting, of the scope of the invention set forth in any accompanying claims.

Finally, throughout the specification and any accompanying claims, unless the context requires otherwise, the word 'comprise' or variations such as 'comprises' or 'comprising' will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

CLAIMS

1. An insulin management method implemented by an insulin delivery system including an insulin delivery device (130), comprising:
 - determining (154, 225) an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of a user to a target blood glucose; and
 - delivering (152, 233) insulin from the insulin delivery device (130) with the insulin in the form of a plurality of correction bolus doses during a fasting period in response to received blood glucose measurements, the correction bolus doses compensated for by a determined insulin on board, wherein for at least a first correction bolus dose of the plurality of correction bolus doses the determined insulin on board equals the assumed insulin on board.
2. The method of claim 1, wherein the insulin delivery device (130) is an automatic insulin delivery device attachable to the user's body for a duration of the fasting period and configured to refrain from administering basal insulin at a preset or default rate or in a preset or default pattern.
3. The method of claim 1 or claim 2, further comprising, at the start of the delivery from the insulin delivery device (130), calculating the assumed external dose to correct an initial blood glucose measurement of the user to the target blood glucose.
4. The method of any one of the preceding claims, wherein the determined insulin on board is a combination of at least the assumed insulin on board and a known delivered insulin from the delivery device (130) during the fasting period once insulin is delivered.
5. The method of any one of the preceding claims, further comprising:
 - calculating (231) each of the plurality of correction bolus doses by comparing an evaluated blood glucose measurement to the target blood glucose to obtain a difference, adjusting the difference by a user insulin sensitivity factor to obtain a resultant dose amount, and reducing the resultant dose amount by the determined insulin on board.
6. The method of claim 5, wherein the correction bolus doses are calculated based on a user's insulin sensitivity factor obtained for the user.
7. The method of claim 6, wherein the user's insulin sensitivity factor is derived from a total daily basal dose information used in a defined period prior to the fasting period.

8. The method of any one of claims 5 to 7, wherein the correction bolus doses are calculated based on at least one of a fixed target blood glucose for all users and a fixed insulin action time for all users.

9. The method of any one of claims 5 to 8, wherein the evaluated blood glucose measurement is evaluated (229) at least in part by smoothing the received blood glucose measurements with a low pass filter to reduce the effect of noise and/or abrupt perturbations to obtain blood glucose values.

10. The method of any one of claims 5 to 9, wherein the evaluated blood glucose measurement is evaluated (229) at least in part by retaining a received blood glucose measurement that is less than a rolling average of a predetermined number of prior received blood glucose measurements and retaining the rolling average for the received blood glucose measurement otherwise.

11. The method of any one of claims 5 to 10, wherein the evaluated blood glucose measurement is evaluated (229) at least in part by projecting a downward trend of the received blood glucose measurements forward and adding the downward trend to the blood glucose measurement value used in the dose calculation.

12. The method of claim 11, wherein the downward trend is determined based at least in part on a largest negative slope between any received blood glucose measurement within a predetermined timeframe and a reference blood glucose measurement.

13. The method of any one of claims 5 to 12, wherein the evaluated blood glucose measurement is evaluated (229) at least in part by fitting received blood glucose measurements within a predetermined timeframe to a trend having an average slope selected from a plurality of regression fit slopes for different rolling subsets of received blood glucose measurements within the predetermined timeframe.

14. The method of any one of claims 5 to 13, wherein the evaluated blood glucose measurement is evaluated (229) at least in part by filtering the received blood glucose measurements, the filtering comprising:

imposing a progressively increasing limit on how much each next received blood glucose measurement can increase compared to the previous received blood glucose measurement for increasing received blood glucose measurements; and

amplifying how much each next received blood glucose measurement decreases compared to the previous received blood glucose measurement for decreasing received blood glucose measurements.

15. The method of any one of the preceding claims, comprising limiting the correction bolus doses to a defined maximum dose per correction bolus dose such that the correction bolus dose is a divided portion of a total correction bolus dose.

16. An insulin management method implemented by a controller (132) of an insulin delivery device (130) for delivering insulin during a fasting period from the delivery device (130) in the form of a wearable automated insulin delivery device, comprising:

- determining a user insulin sensitivity factor;
- receiving (223, 228) blood glucose measurements;
- evaluating (229) the blood glucose measurements to obtain evaluated blood glucose values;

- determining (225) an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose;

- calculating (231) periodic correction bolus doses by comparing an evaluated blood glucose value to a target blood glucose to obtain a difference, the difference adjusted by the user insulin sensitivity factor to obtain a resultant dose amount, and the resultant dose amount compensated by a determined insulin on board, wherein:

- correction bolus doses in an initial period are calculated using the determined insulin on board set equal to the assumed insulin on board; and

- delivering (233) at least a portion of a calculated correction dose at periodic time intervals.

17. The method of claim 16, wherein the assumed insulin on board is initially assumed to be sufficient to bring an initial blood glucose measurement into a target range and is reduced over time during the fasting period.

18. The method of claim 16 or claim 17, including adjusting (230) the assumed insulin on board over time based on comparisons between to the evaluated blood glucose measurement.

19. The method of any one of claims 16 to 18, wherein the determined insulin on board includes a known delivered insulin from delivered correction doses from the delivery device (130) during the fasting period.

20. The method of any one of claims 16 to 19, including dividing the correction dose into delivery portions with a maximum delivery rate for a maximum amount of insulin to be delivered over a given time period.
21. The method of any one of claims 16 to 20, including determining an initial user insulin sensitivity factor for the fasting period based on a received total daily basal dose information.
22. The method of claim 21, including adjusting the initial user insulin sensitivity factor by a sensitivity safety factor configured to bias the calculating periodic correction bolus doses to less insulin dosage.
23. The method of any one of claims 16 to 22, including adjusting (230) the target blood glucose by a target safety factor based at least in part on a difference between a received blood glucose measurement and the target blood glucose.
24. The method of any one of claims 16 to 23, including adjusting the calculated correction bolus dose by an overall safety factor configured to limit the calculated bolus dose to a maximum delivery rate for insulin to be delivered over a time period between delivery of correction bolus doses.
25. The method of any one of claims 16 to 24, wherein the target blood glucose is time varying to decrease over time during the fasting period and a rate of decrease over time of the target blood glucose is determined based on an assumption that blood glucose levels are being lowered by existing externally administered insulin administered prior to the fasting period.
26. The method of any one of claims 16 to 25, wherein the user insulin sensitivity factor is initially set at a predetermined value and adjusted over time based at least in part on a difference between received blood glucose measurements and expected blood glucose.
27. The method of any one of claims 16 to 26, wherein evaluating (229) the blood glucose measurements includes filtering for increasing blood glucose values and not filtering for decreasing blood glucose values.
28. The method of any one of claims 16 to 27, wherein evaluating (229) the blood glucose measurements includes adjusting for a long term downward trend over a period of hours in the fasting period.

29. The method of any one of claims 16 to 28, wherein delivering (233) at least a portion of the correction doses includes delivering a first zero dose.

30. An insulin management system of an insulin delivery device (130, 401) in the form of an automatic insulin delivery device attachable to a user's body for a duration of a fasting period, the system comprising:

a delivery component (420) of the insulin delivery device (130, 401) configured to deliver insulin in the form of a plurality of correction bolus doses in response to received blood glucose measurements, the correction bolus doses compensated for by a determined insulin on board, wherein for at least a first correction bolus dose of the plurality of correction bolus doses the determined insulin on board equals an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose.

31. The system of claim 30, wherein the delivery component (420) includes an insulin on board determining component (443) including an assumed insulin on board component (444) configured to calculate an initial assumed correction dose to correct an initial blood glucose measurement of the user to a target blood glucose.

32. The system of claim 31, wherein the insulin on board determining component (443) also includes a device insulin on board component (445) and the correction bolus doses of the fasting period are calculated based on assumed insulin on board and known delivered insulin from the delivery device (130).

33. The system of any one of claims 30 to 32, wherein the delivery component (420) includes an activation component (446) for detecting activation of the delivery device (130) to commence delivery of insulin from the fasting insulin delivery device (130).

34. The system of any one of claims 30 to 33, wherein the delivery component (420) includes a correction dose limiting component (454) configured to limit the correction bolus doses for the fasting period to a defined maximum dose given at any time point to minimize sudden corrections.

35. The system of claim 34, wherein the correction dose limiting component (454) is configured to limit each of the correction bolus doses for the fasting period to at least a minimum dose deliverable by the delivery device (130, 401) hardware.

36. The system of any one of claims 30 to 35, wherein the delivery component (420) includes a safety factor component (442) configured to provide safety factors to parameters on which the dose correction is based.

37. The system of any one of claims 30 to 36, wherein the delivery component (420) includes an end-procedure component (455) configured to coordinate an end bolus delivery at the end of the fasting period.
38. The system of any one of claims 30 to 37, wherein the delivery component (420) includes:
an insulin sensitivity factor receiving component (441) configured to determine a user insulin sensitivity factor;
a blood glucose measurement receiving component (451) configured to periodically receive blood glucose measurements;
a blood glucose measurement evaluating component (452) configured to evaluate the blood glucose measurements;
a correction dose calculating component (454) configured to calculate the periodic correction bolus; and
the delivery component (420) delivering at least a portion of a calculated correction dose at time intervals.
39. The system of claim 38, wherein the insulin sensitivity factor receiving component (441) is configured to derive an initial insulin sensitivity factor from a total daily basal dose information received from a non-fasting insulin management modality in a defined period prior to the fasting period for use in determining the correction bolus doses.
40. The system of claim 38 or claim 39, wherein the correction dose calculating component (453) is configured to determine the correction bolus doses for the fasting period at each blood glucose measurement timepoint to determine if insulin is required to bring the user to a target blood glucose.
41. The system of any one of claims 38 to 40, wherein the blood glucose measurement evaluating component (452) is configured to perform at least one of:
smoothing the received blood glucose measurements with a low pass filter to reduce the effect of noise and/or abrupt perturbations to obtain blood glucose values;
retaining a received blood glucose measurement that is less than a rolling average of a predetermined number of prior received blood glucose measurements and retaining the rolling average for the received blood glucose measurement if the received blood glucose is not less than the rolling average;
projecting a downward trend of the received blood glucose measurements forward and adding the downward trend to the blood glucose measurement value used in the dose calculation;

filtering the received blood glucose measurements, the filtering comprising imposing a progressively increasing limit on how much each next received blood glucose measurement can increase compared to the previous received blood glucose measurement for increasing received blood glucose measurements, and amplifying how much each next received blood glucose measurement decreases compared to the previous received blood glucose measurement for decreasing received blood glucose measurements; and

fitting received blood glucose measurements within a predetermined timeframe to a trend having a median slope selected from a plurality of regression fit slopes for different rolling subsets of received blood glucose measurements within the predetermined timeframe.

42. The system of any one of claims 30 to 41, including a mobile user computing device (402) comprising:

a processor (802) and a memory (804) configured to provide non-transitory, computer-readable program instructions to the processor (802) to execute functions of components:

a basal insulin input component (813) for requesting a value from a user of a total daily basal dose information used in a defined period prior to the fasting period; and

a controller pairing component (814) for pairing the mobile user computing device (402) to a controller (132, 410) of the delivery device (130, 401).

43. An automatic insulin delivery device (130) attachable to a user's body for a duration of a fasting period, the device (130) comprising:

a durable portion including a delivery component configured to control a delivery of insulin in the form of a plurality of correction bolus doses in response to received blood glucose measurements, at least the first correction bolus dose of the plurality of correction bolus doses determined based on a determined insulin on board equal to an assumed insulin on board that is determined based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose; and

a disposable portion including a reservoir (432) configured to contain insulin and configured to automatically deliver the correction bolus doses to the user.

44. The device of claim 43, wherein the reservoir (432) is configured to be fillable from a non-fasting insulin injection device used during a non-fasting period.

45. A computer-implemented method for managing delivery of insulin during a fasting period from a delivery device (130) in the form of a wearable automated insulin delivery device worn for the fasting period, wherein the method is carried out by a computing application provided at a mobile user computing device (402), the method comprising:

requesting (703) a value from a user of a total daily basal dose information used in a defined period prior to the fasting period;

pairing (704) the mobile user computing device to a controller (132, 410) of the delivery device (130, 401), the controller (132, 410) configured to control a delivery of insulin in the form of a plurality of correction bolus doses in response to received blood glucose measurements, the correction bolus doses compensated for by a determined insulin on board, wherein for at least a first correction bolus dose of the plurality of bolus doses the determined insulin on board is equal to an assumed insulin on board based on an assumed external dose calculated to correct an initial blood glucose value of the user to a target blood glucose; and

transmitting and receiving information to and from the controller (132, 410) of the delivery device (130, 401) during the fasting period.

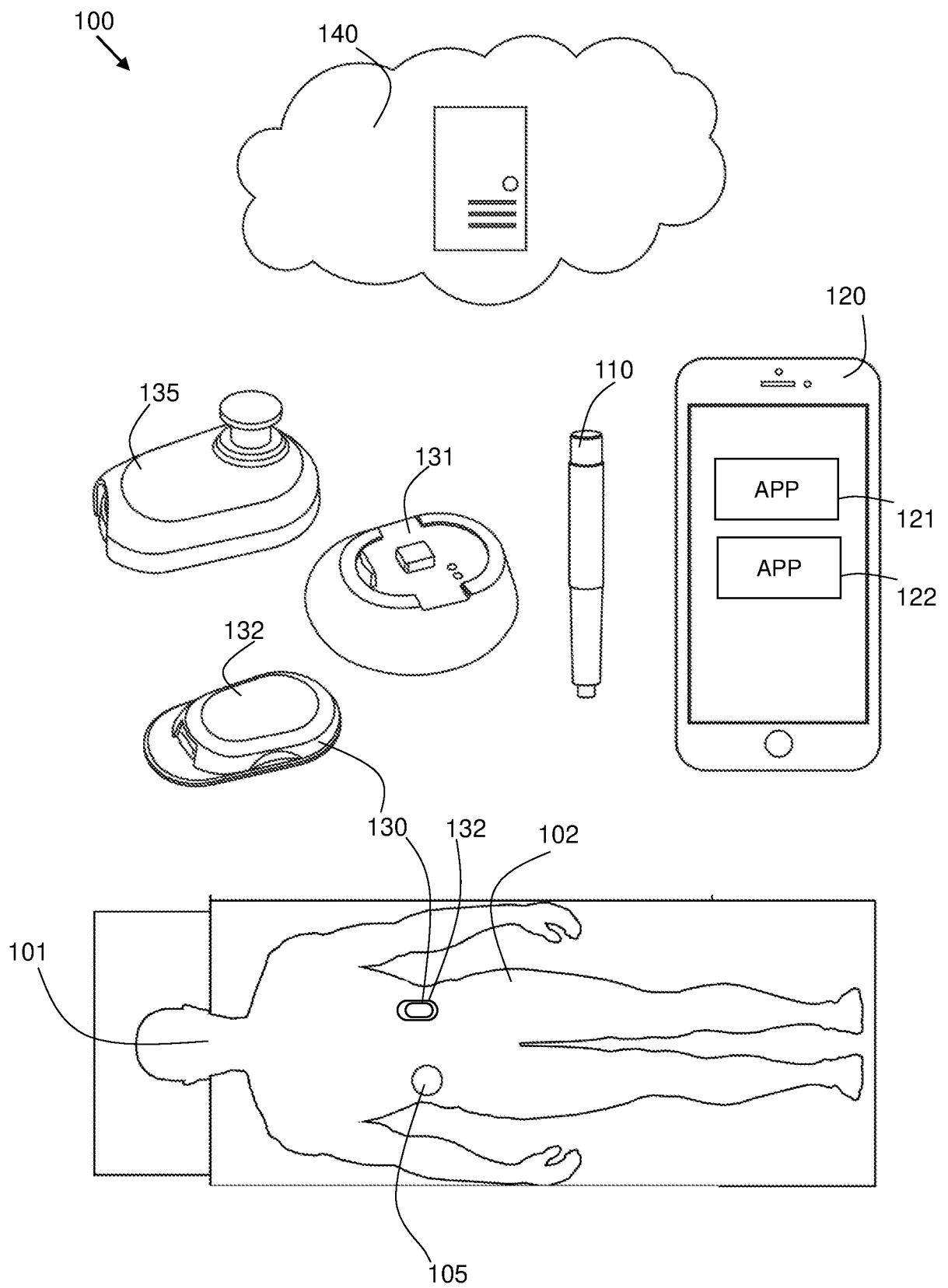
46. The method of claim 45, wherein requesting (703) a value from the user of a total daily basal dose information includes requesting a usual number of units of basal insulin received from a non-fasting form of insulin therapy.

47. The method of claim 45 or claim 46, wherein the method includes pairing (705) the mobile user computing device to a blood glucose monitor to transfer blood glucose measurements to the delivery device (130).

48. The method of any one of claims 45 to 47, wherein the method provides a display of a session history of information relating to the fasting period.

49. The method of any one of claims 45 to 48, wherein the method includes coordinating (724) a fast-ending procedure for the user including dividing a fast-ending meal bolus into a first portion equal to a remaining insulin in the delivery device (130) at the end of the fasting period and a second portion to be delivered to the user utilizing a delivery method other than the delivery device (130) in a non-fasting period immediately following the fasting period.

FIG. 1A



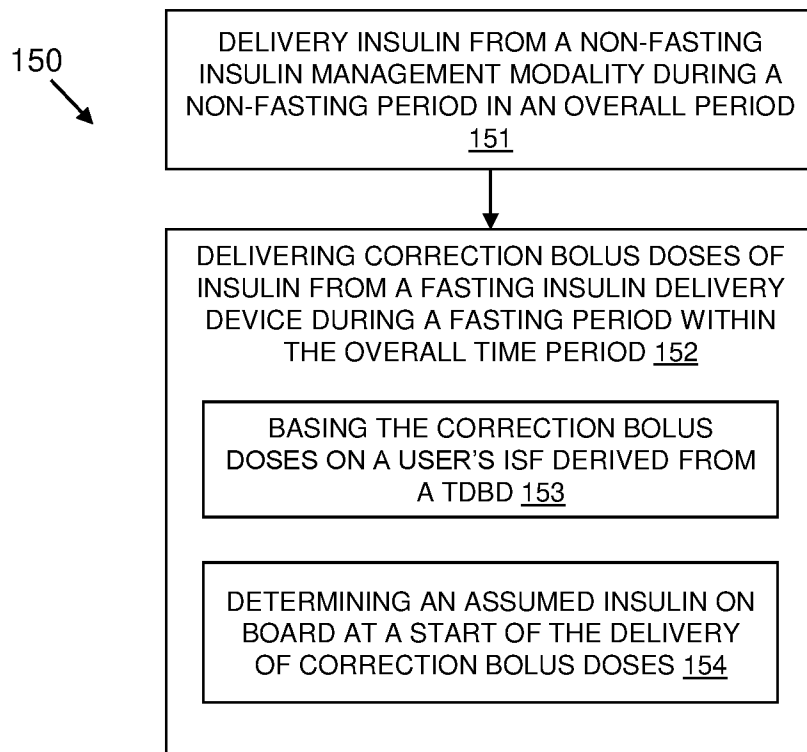


FIG. 1B

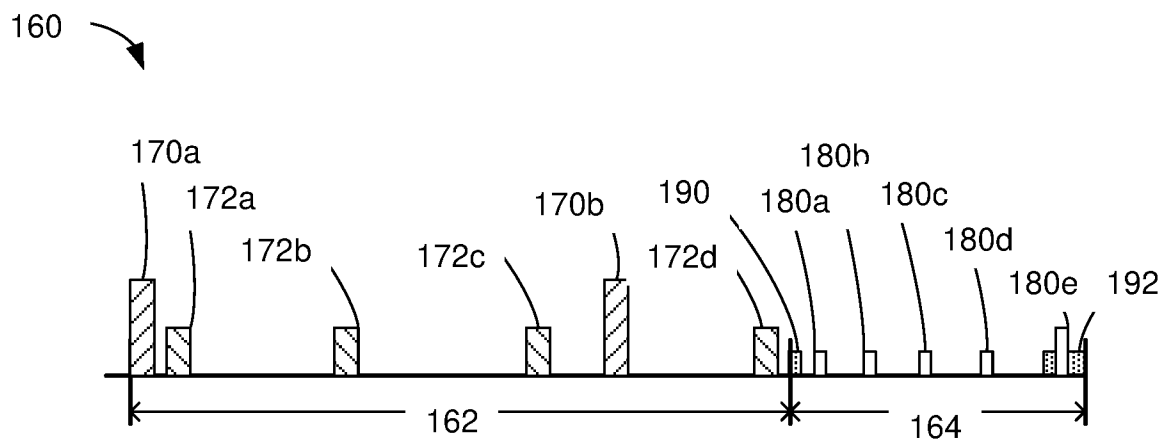


FIG. 1C

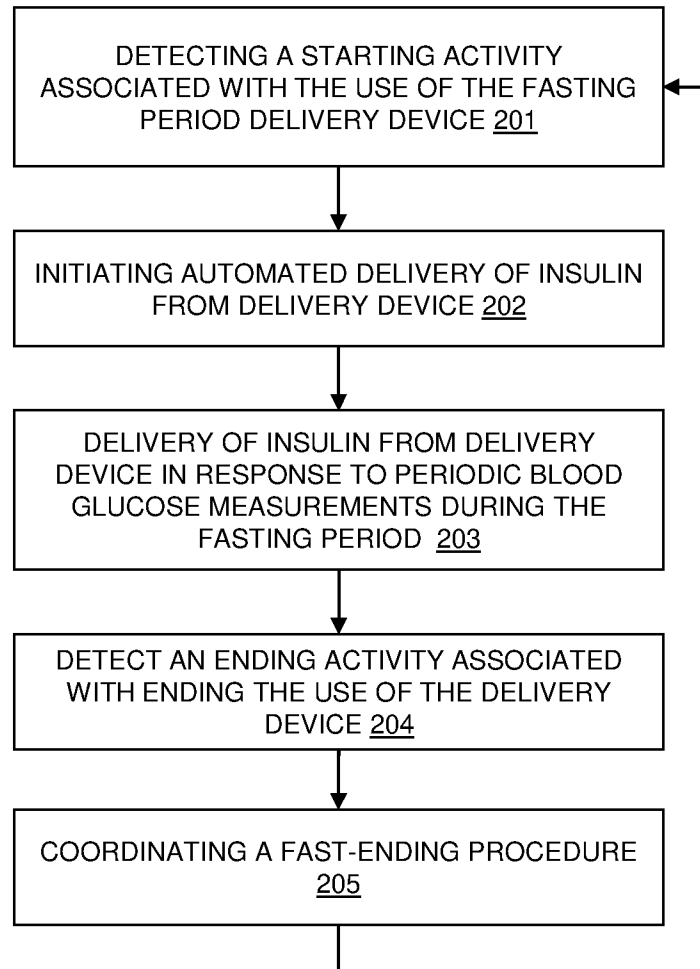
200


FIG. 2A

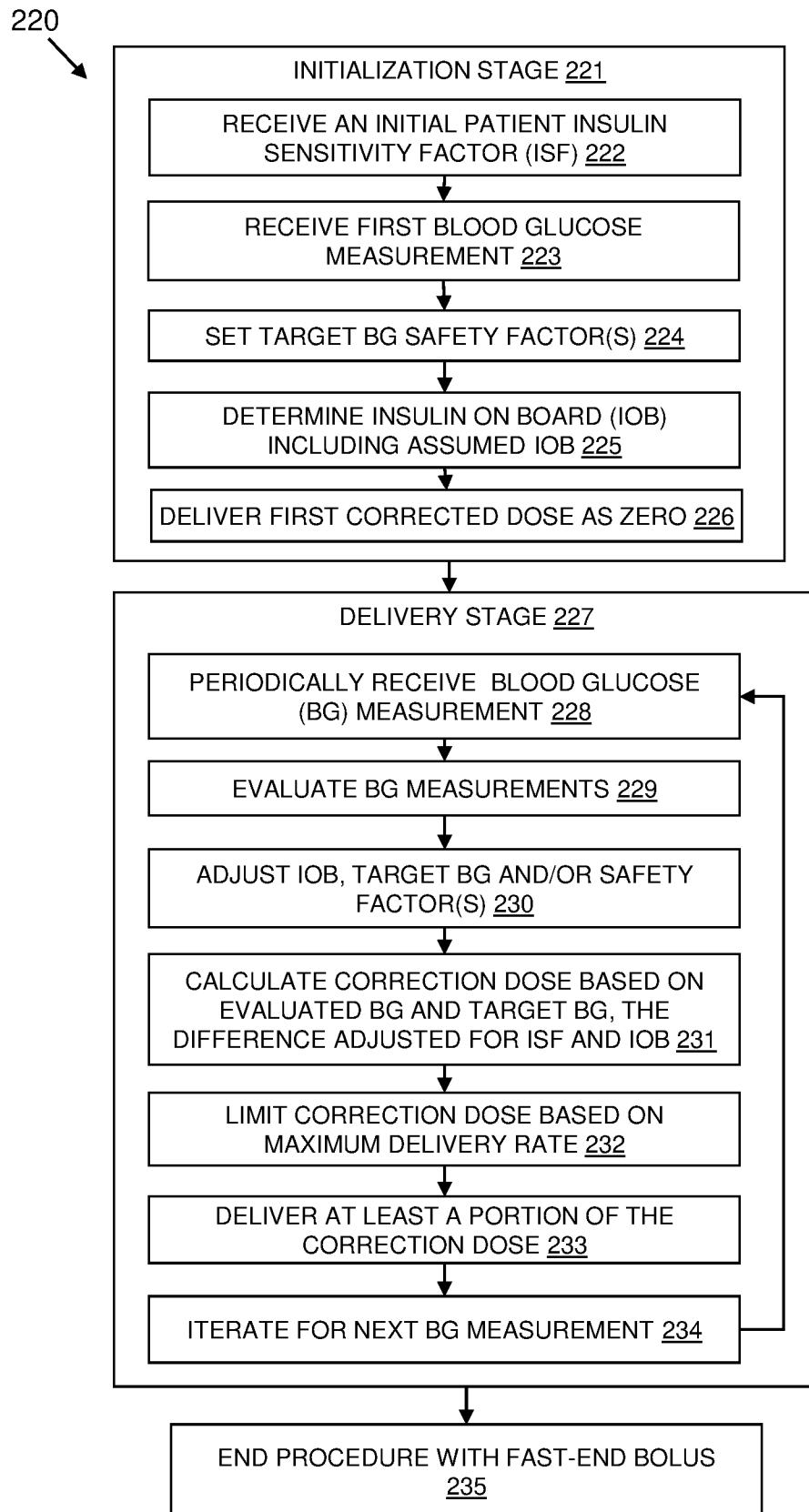


FIG. 2B

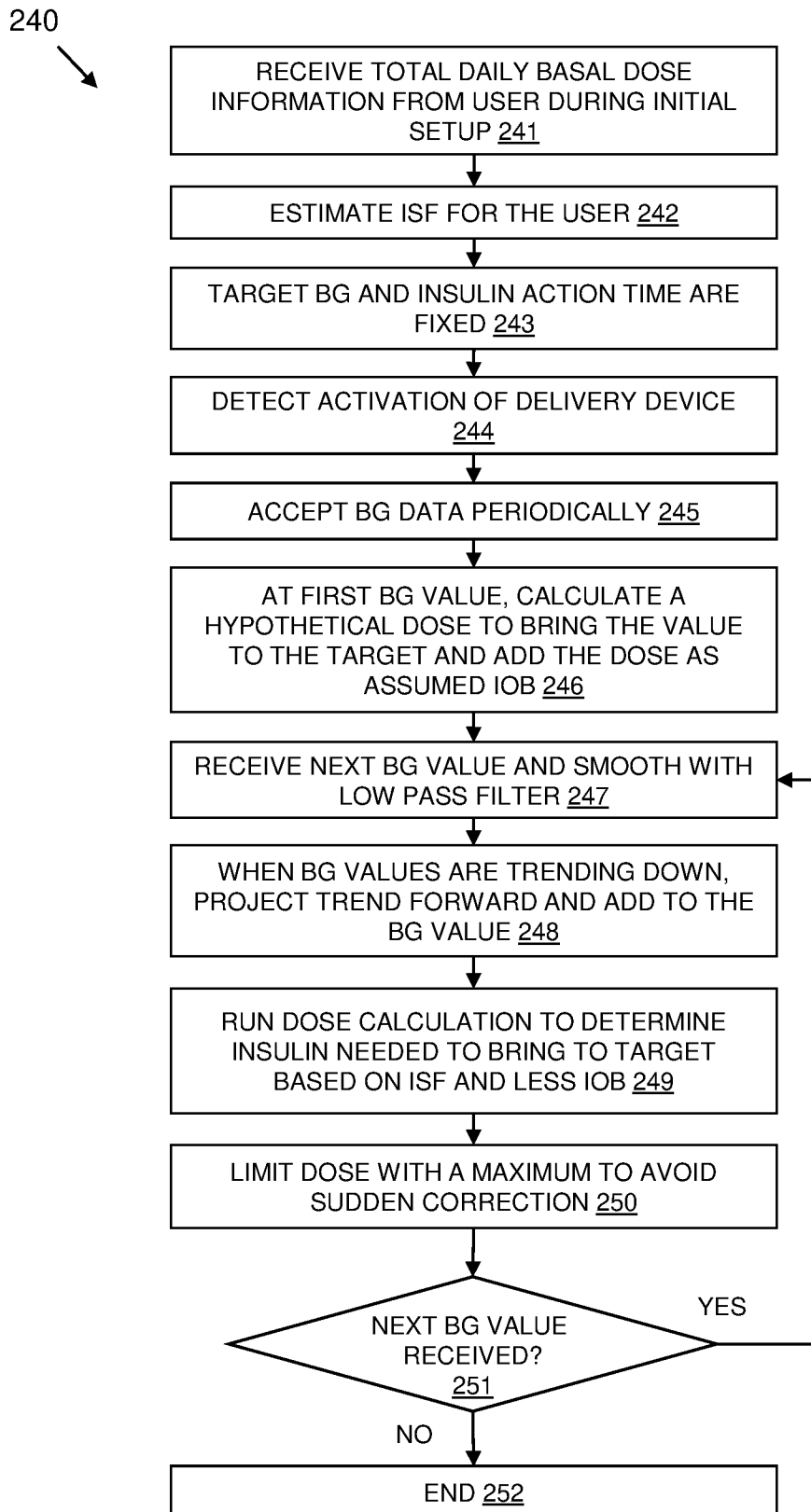


FIG. 2C

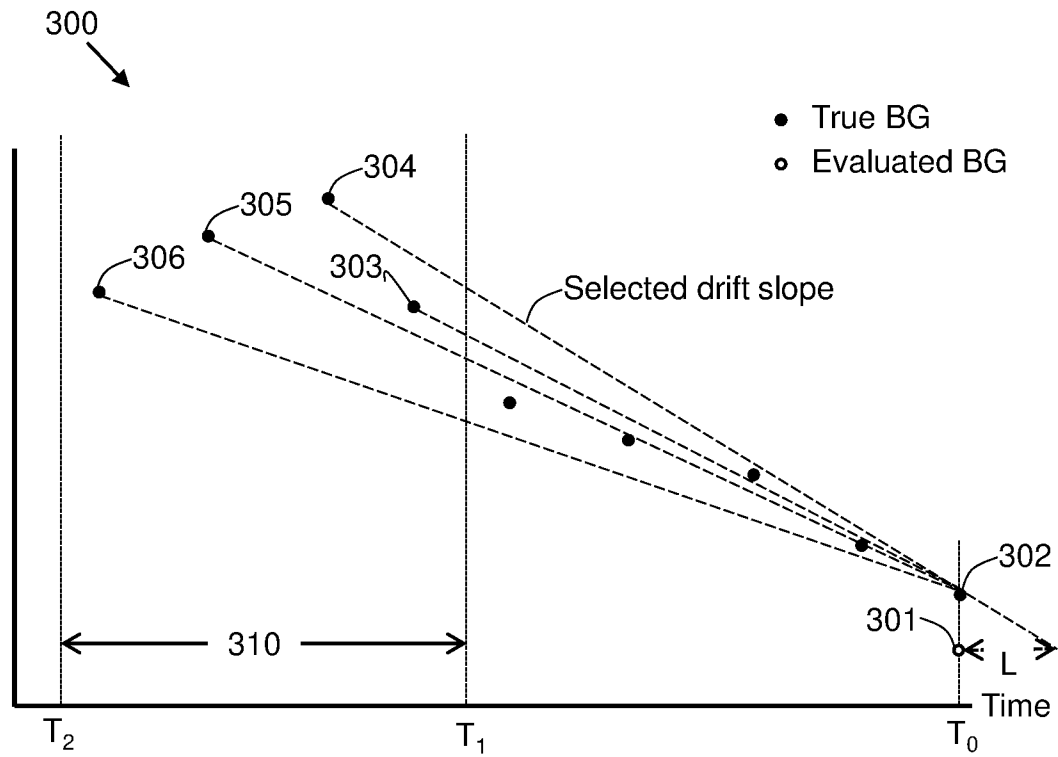


FIG. 3A

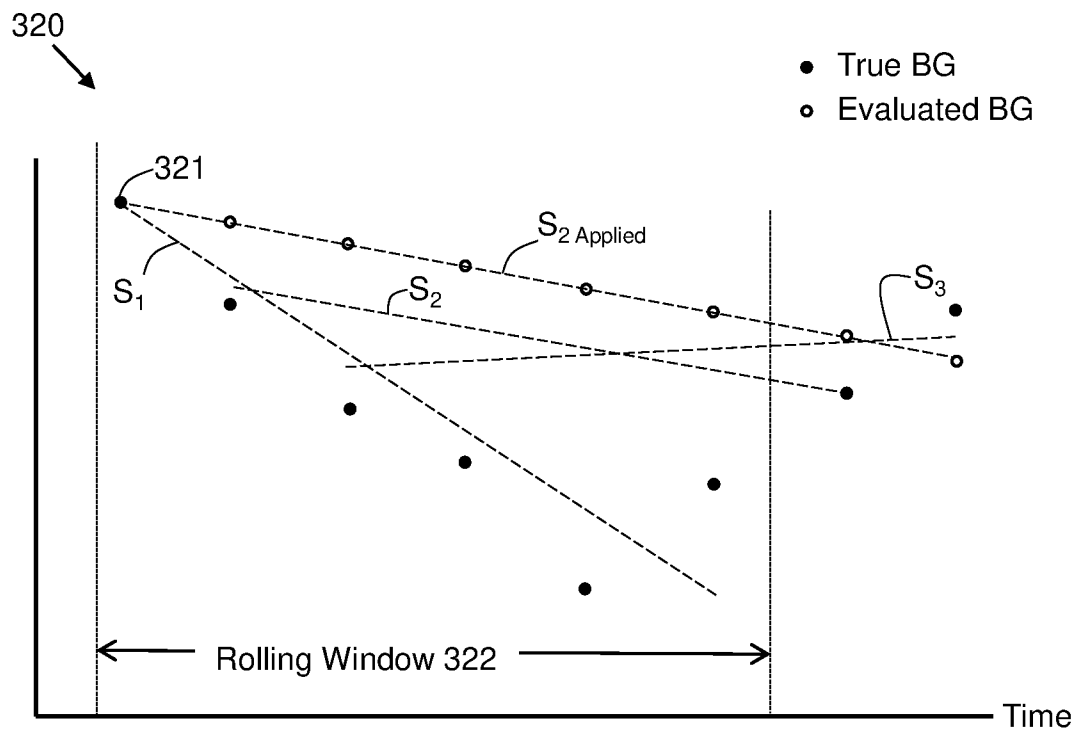


FIG. 3B

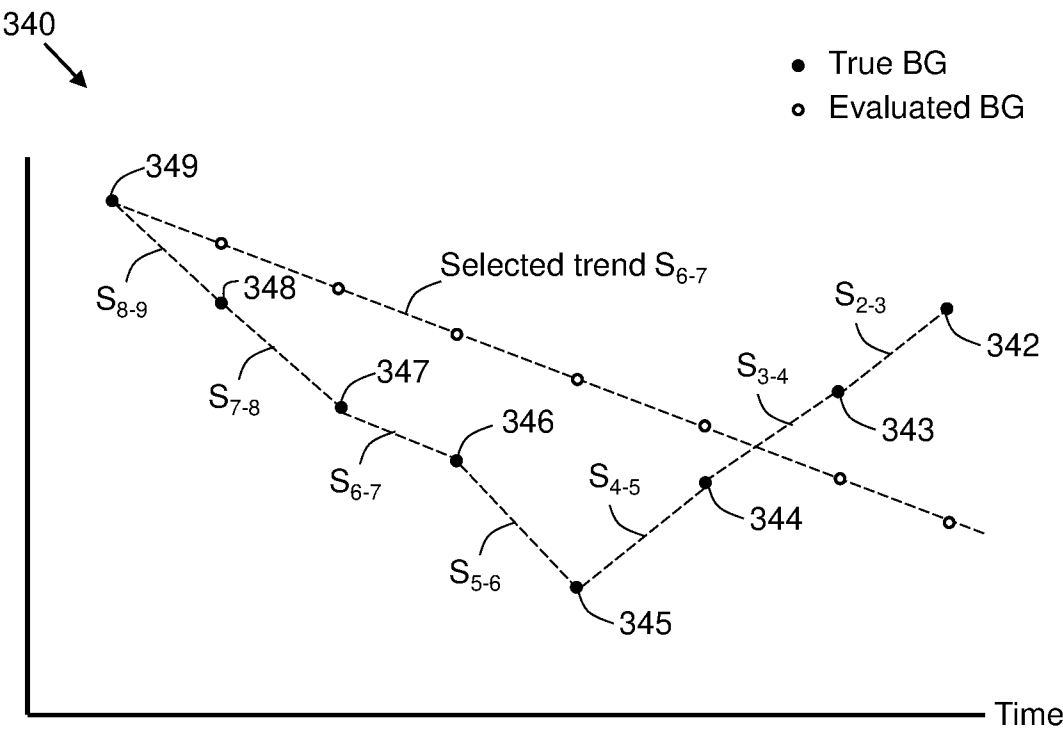


FIG. 3C

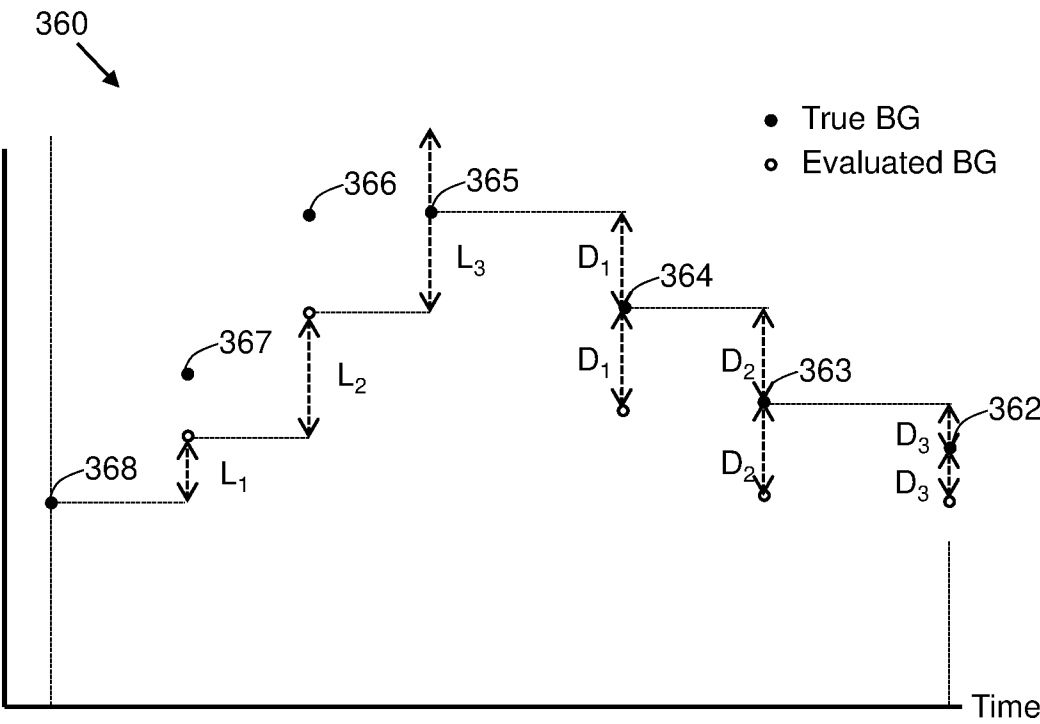


FIG. 3D

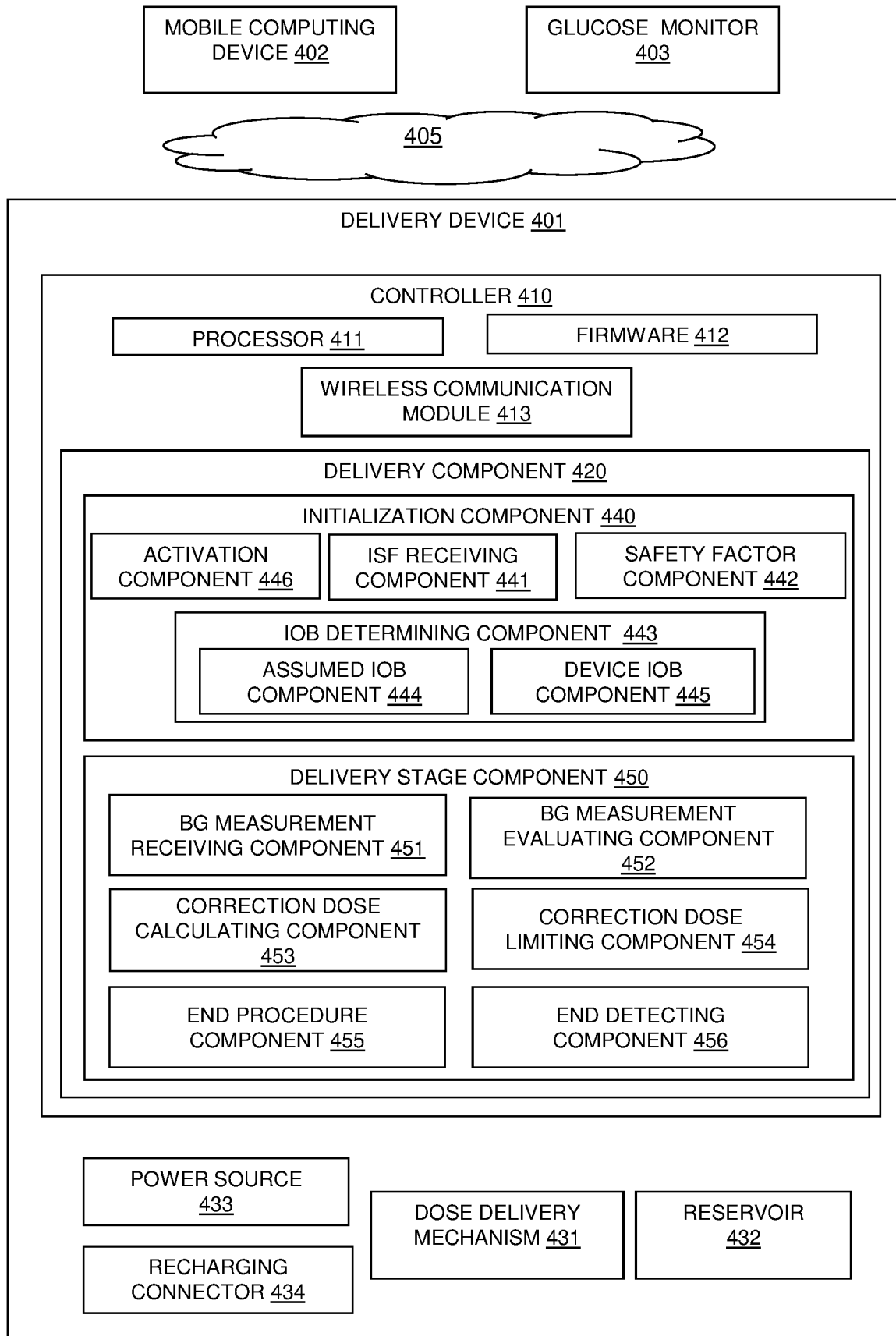


FIG. 4

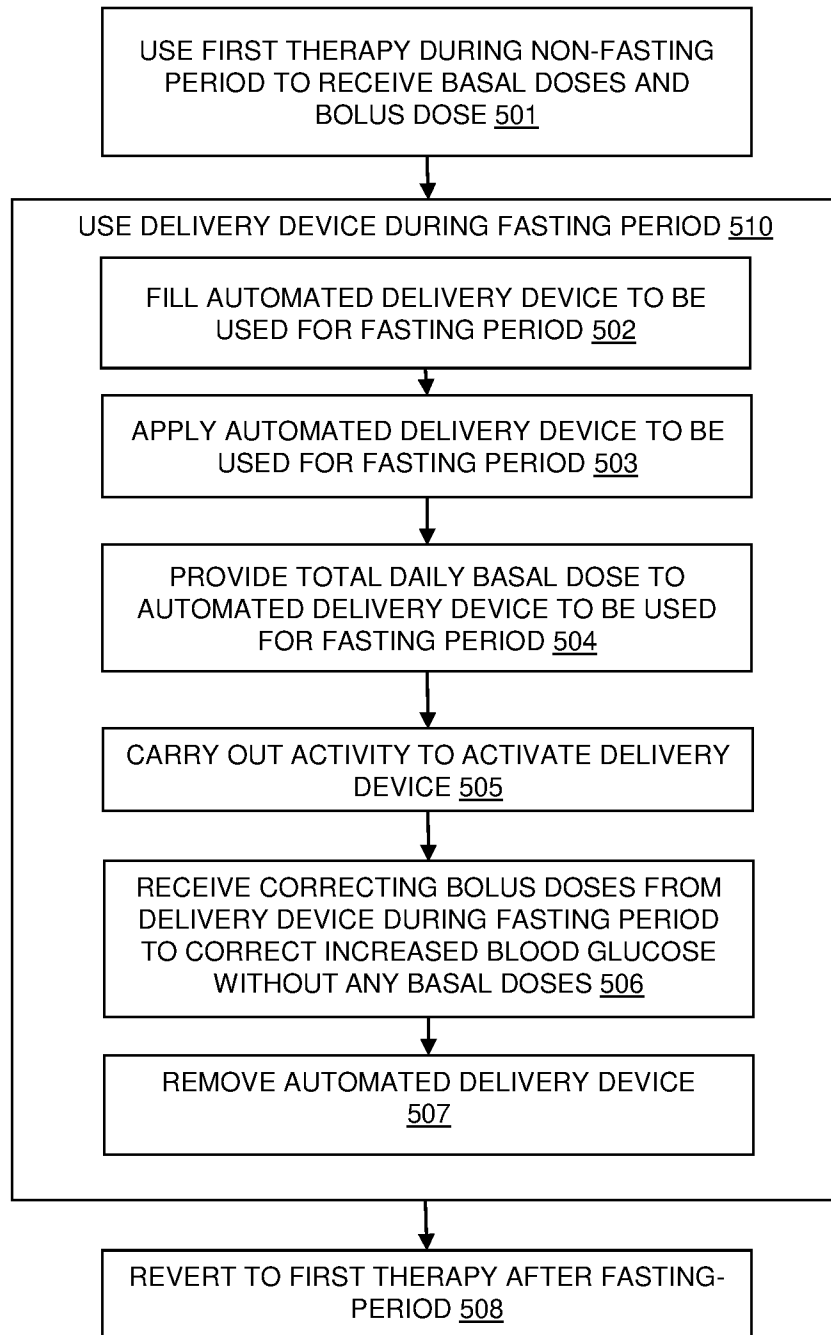
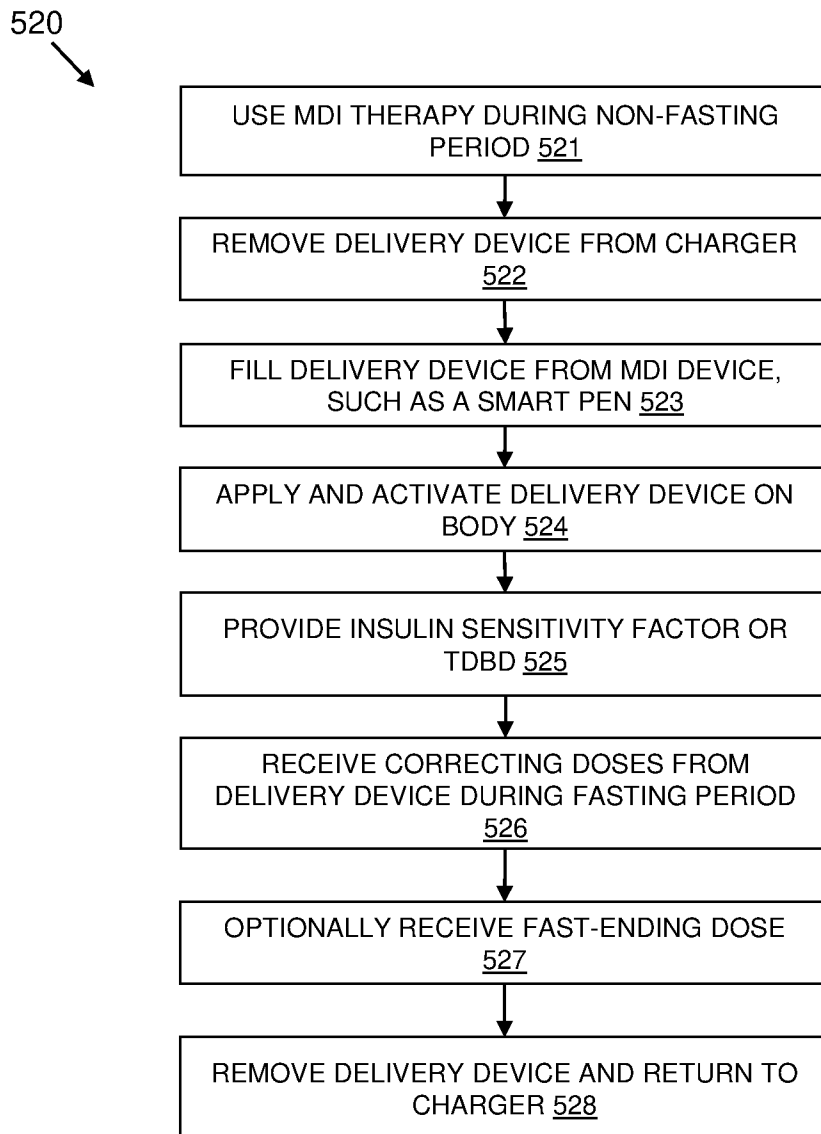
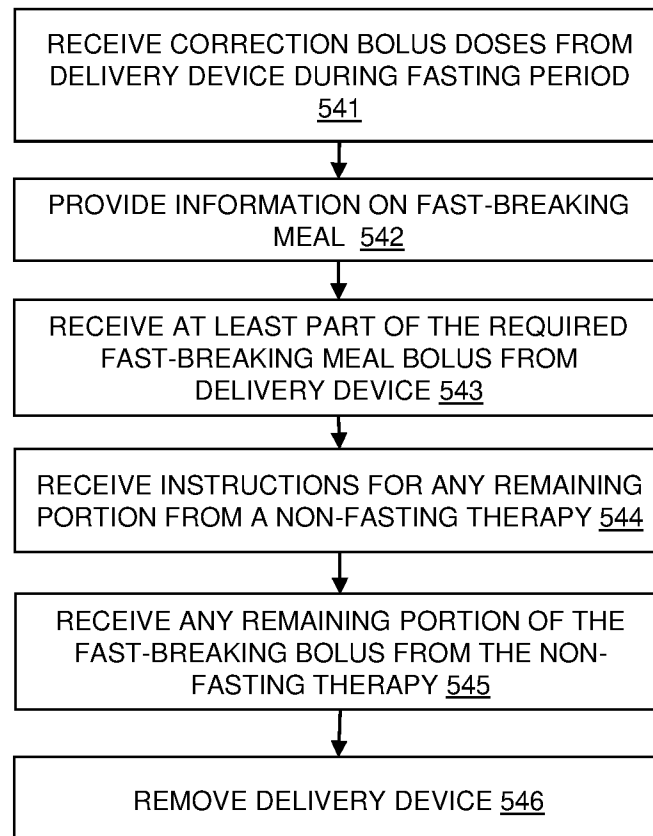
500
↓

FIG. 5A

**FIG. 5B**

540
↓**FIG. 5C**

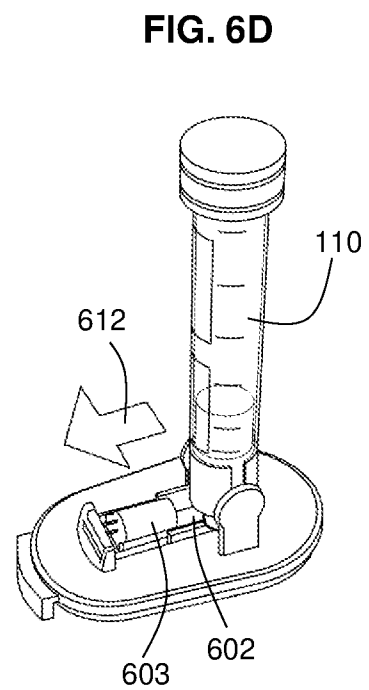
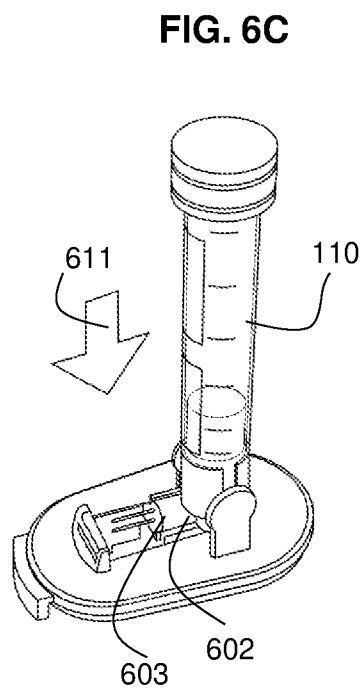
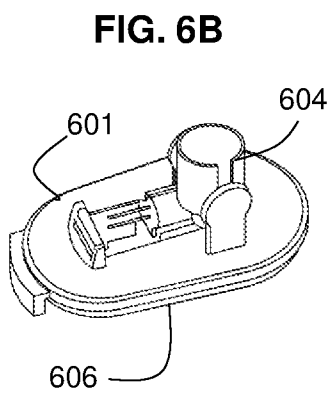
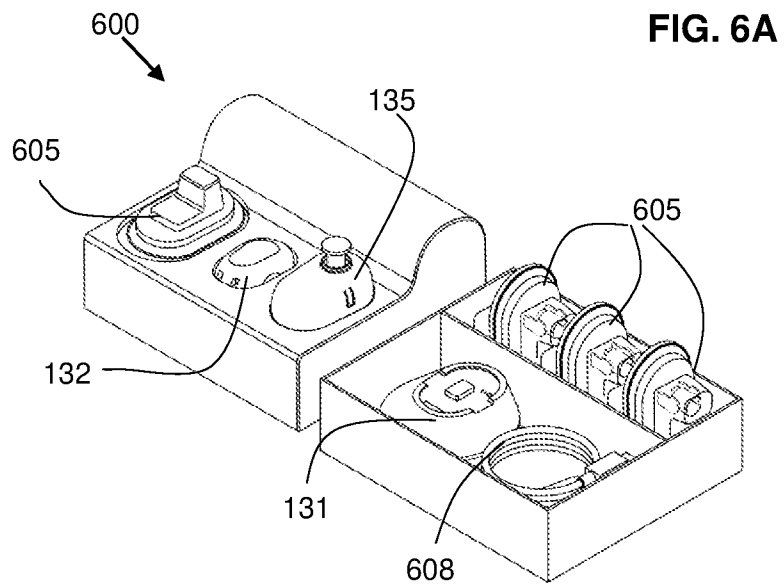


FIG. 6E

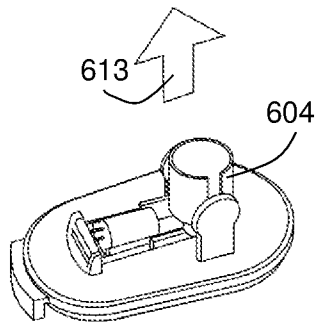


FIG. 6F

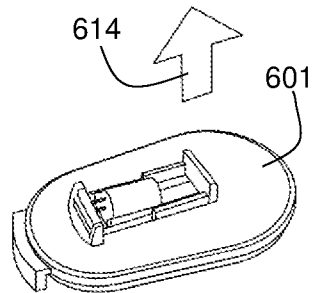


FIG. 6G

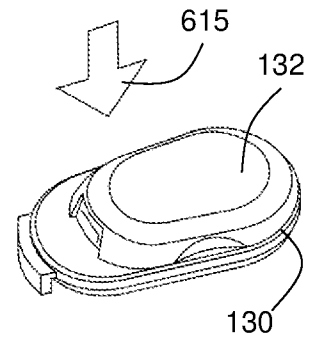


FIG. 6H

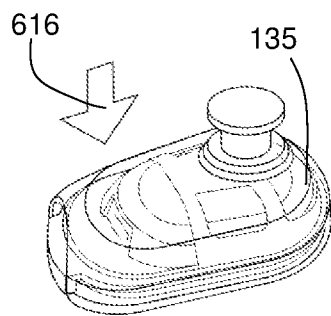


FIG. 6I

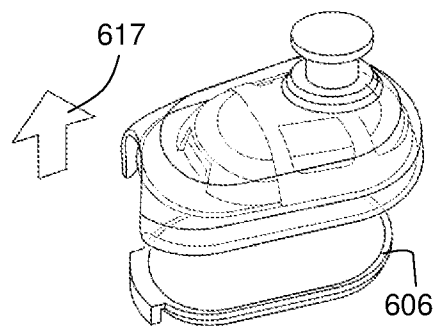


FIG. 6J

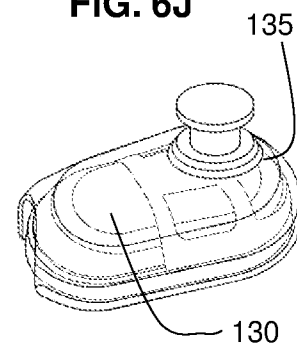


FIG. 6K

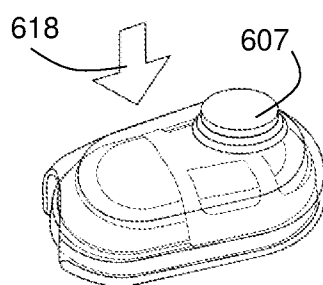


FIG. 6L

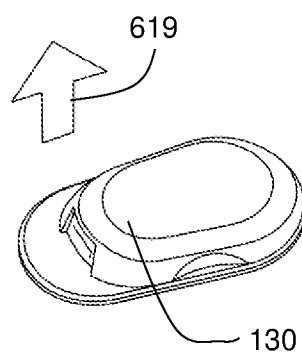
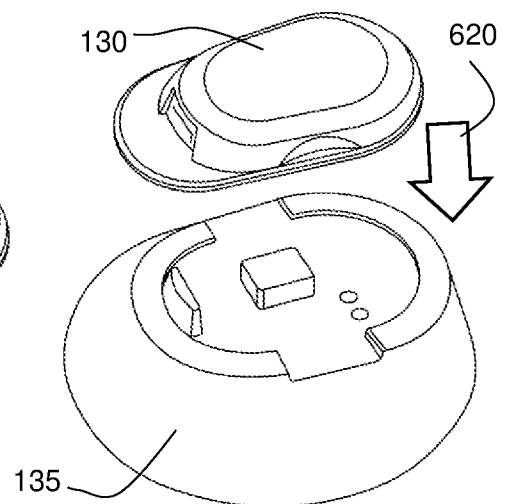


FIG. 6M



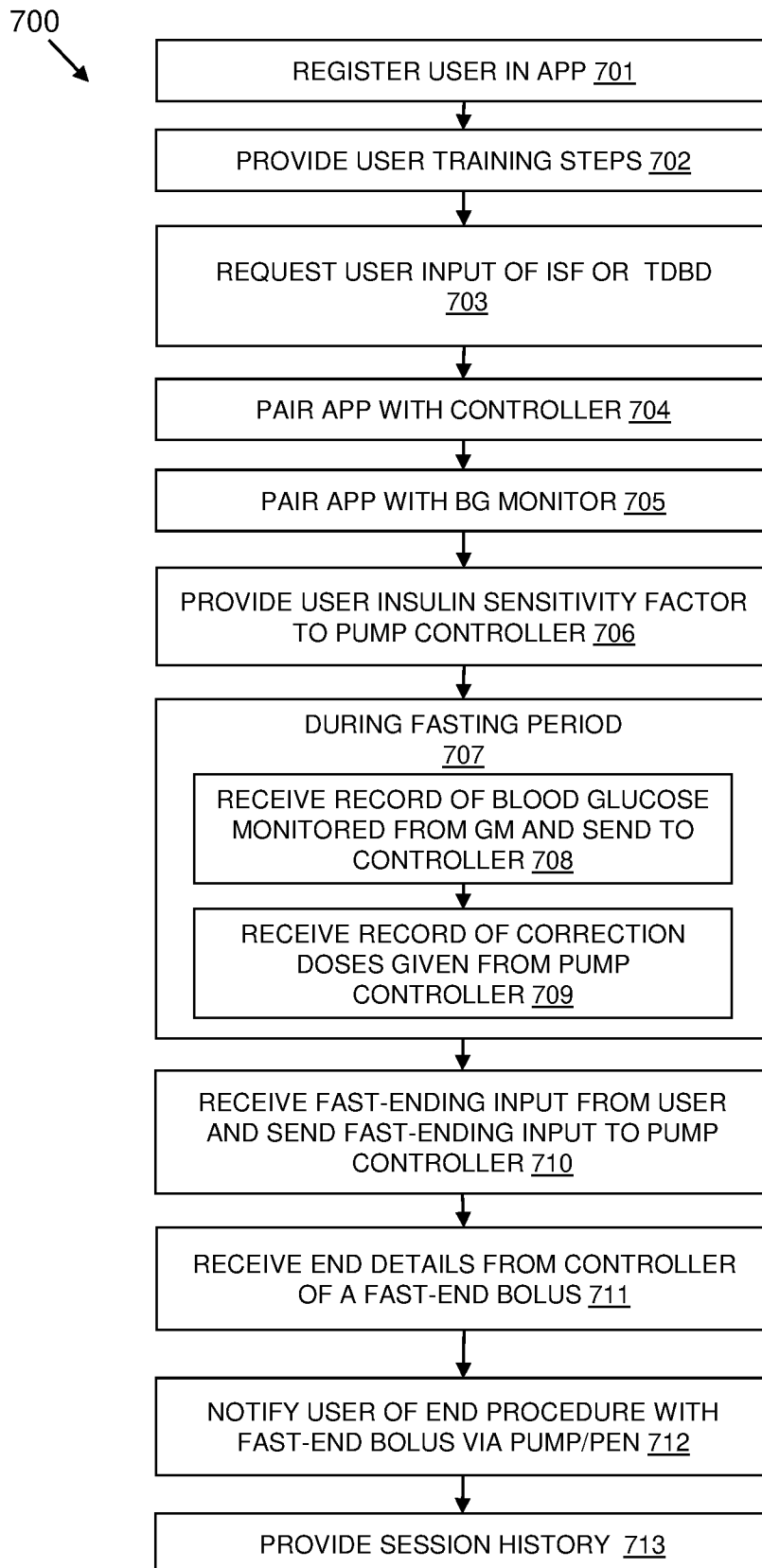
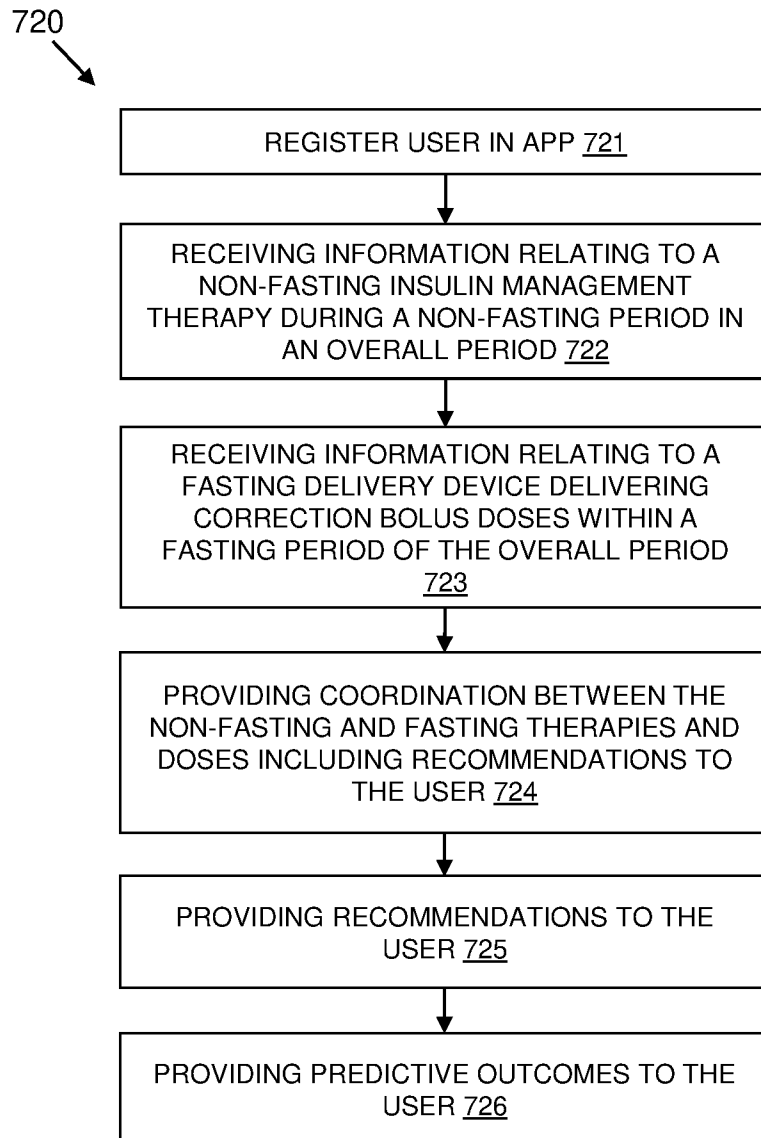


FIG. 7A

**FIG. 7B**

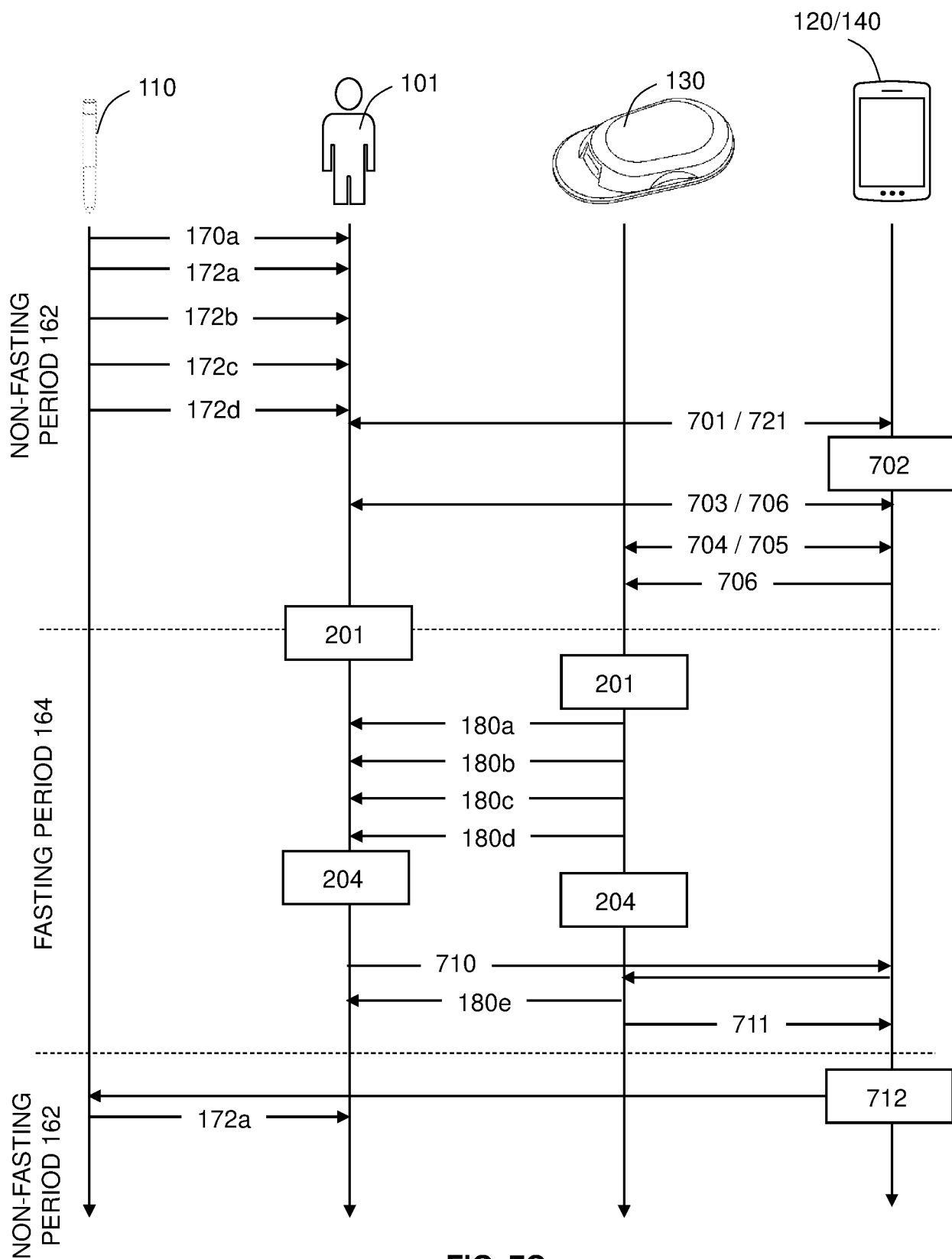
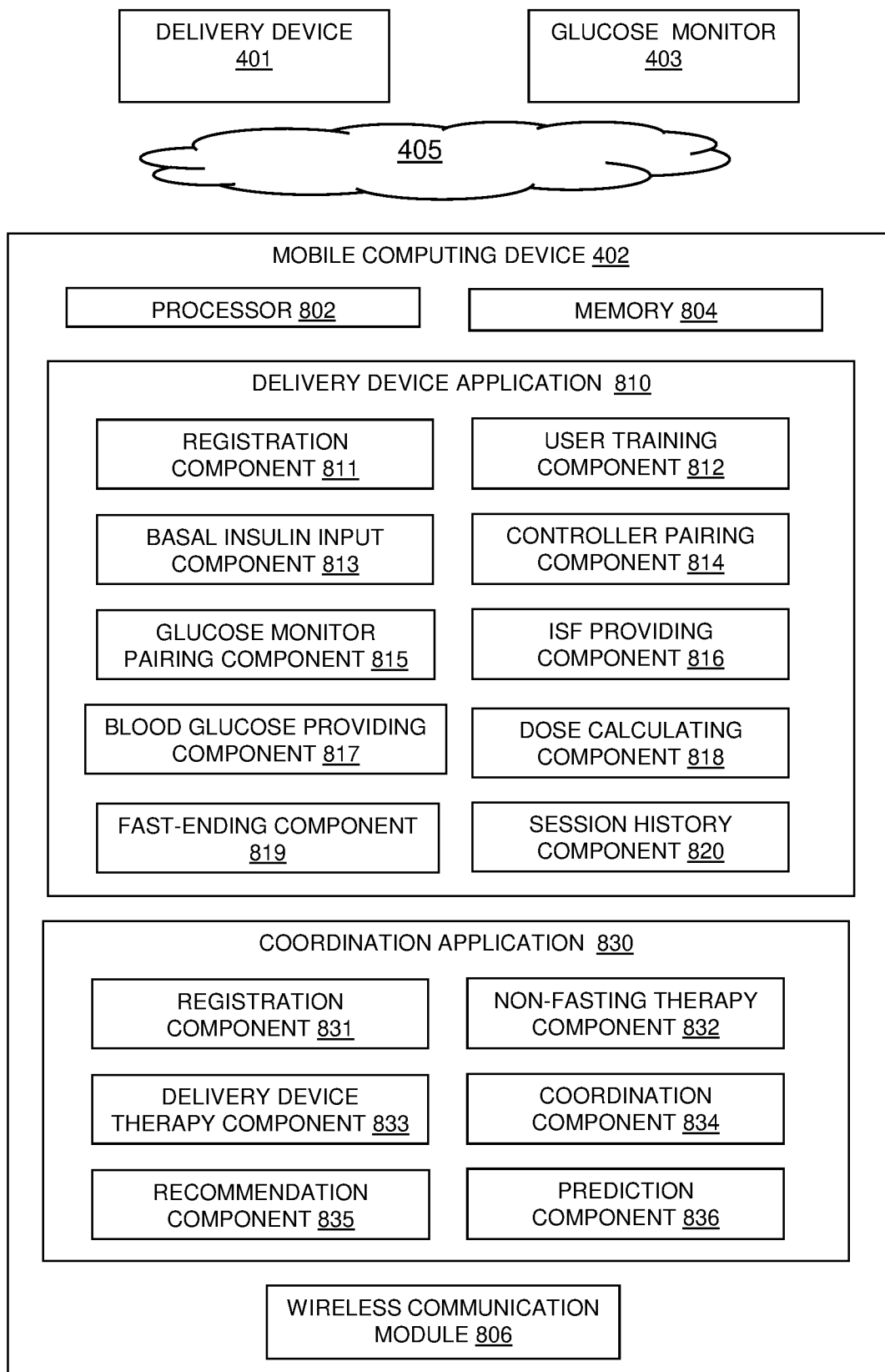


FIG. 7C

**FIG. 8**

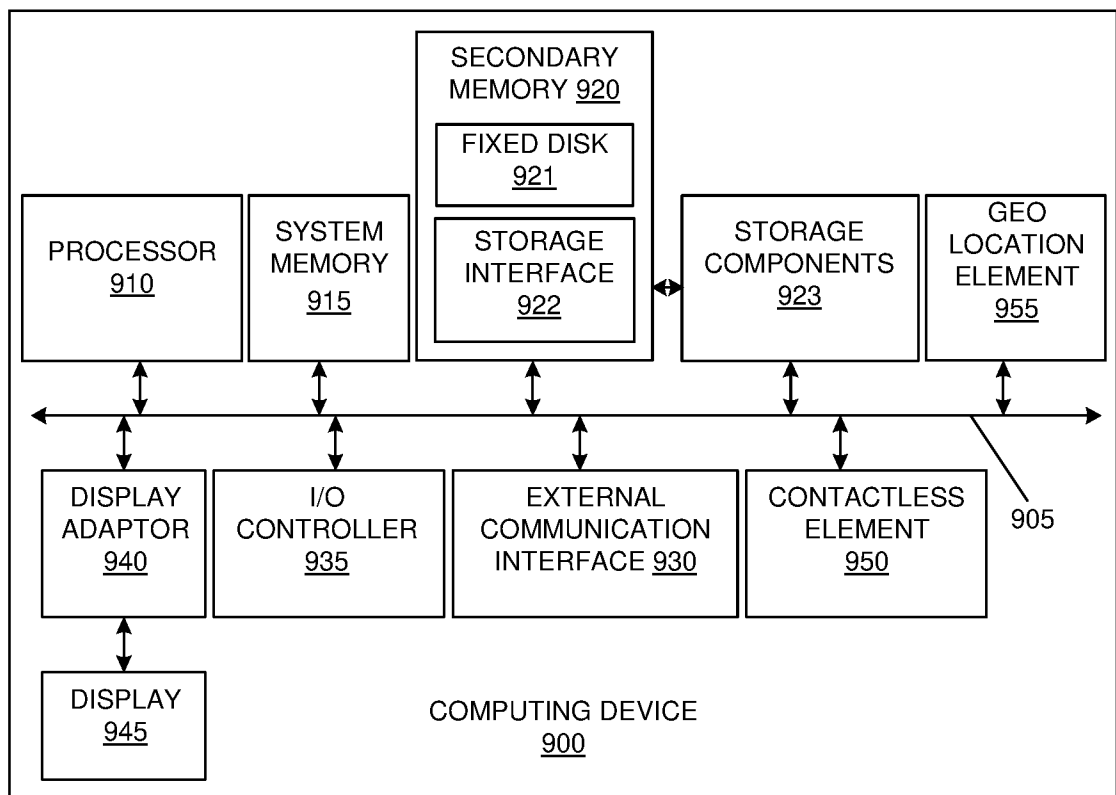
**FIG. 9**

FIG. 10A

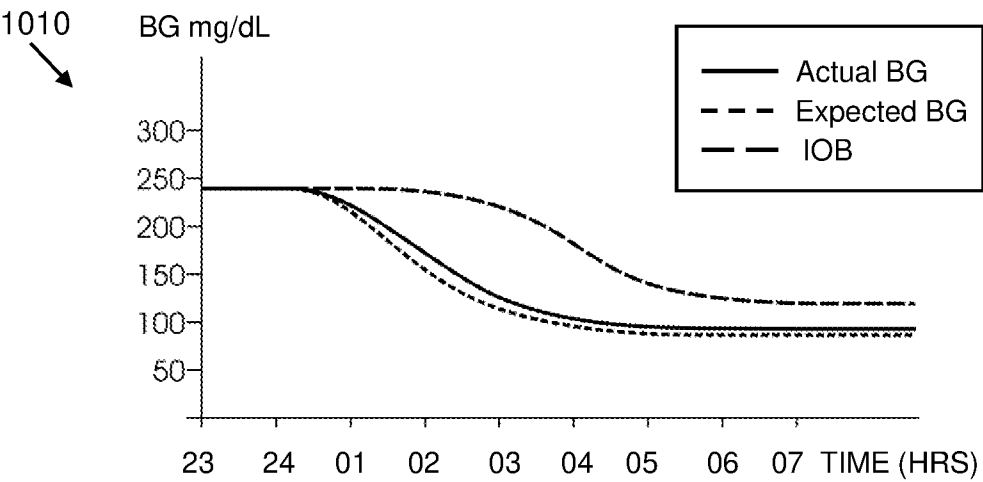


FIG. 10B

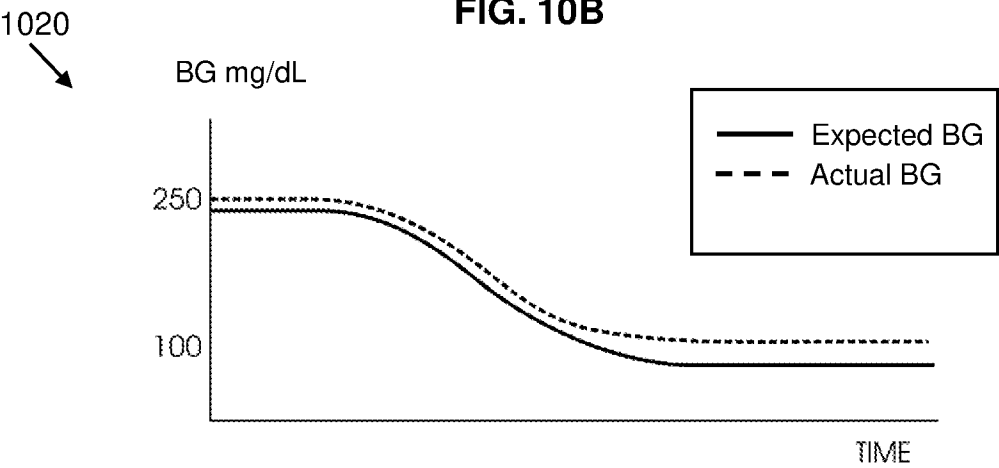


FIG. 10C

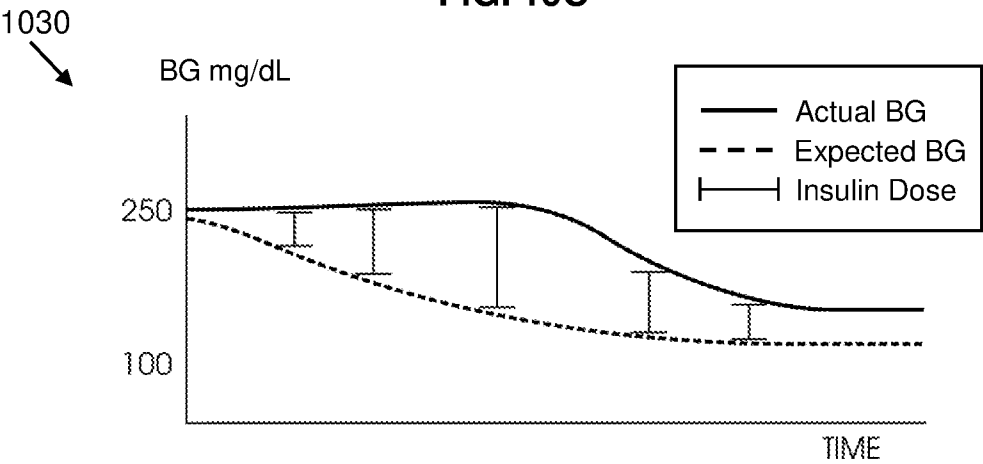


FIG. 10D

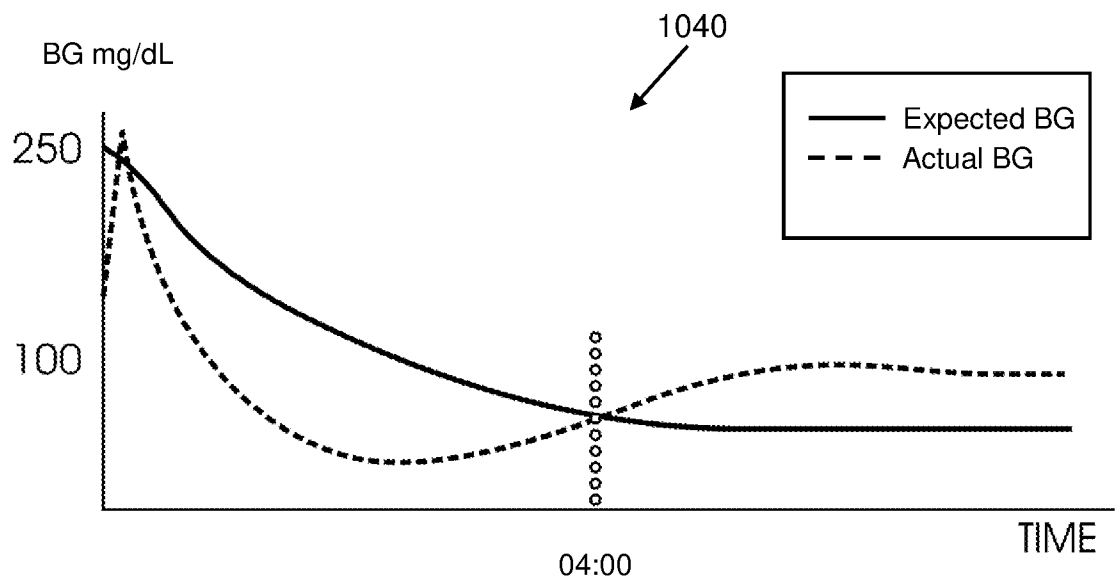
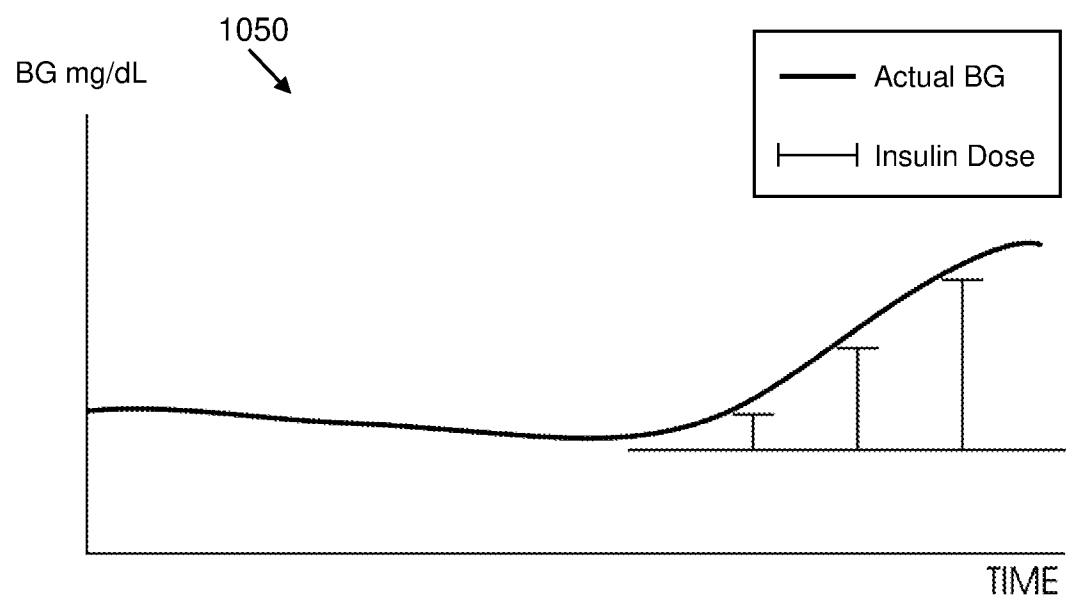


FIG. 10E



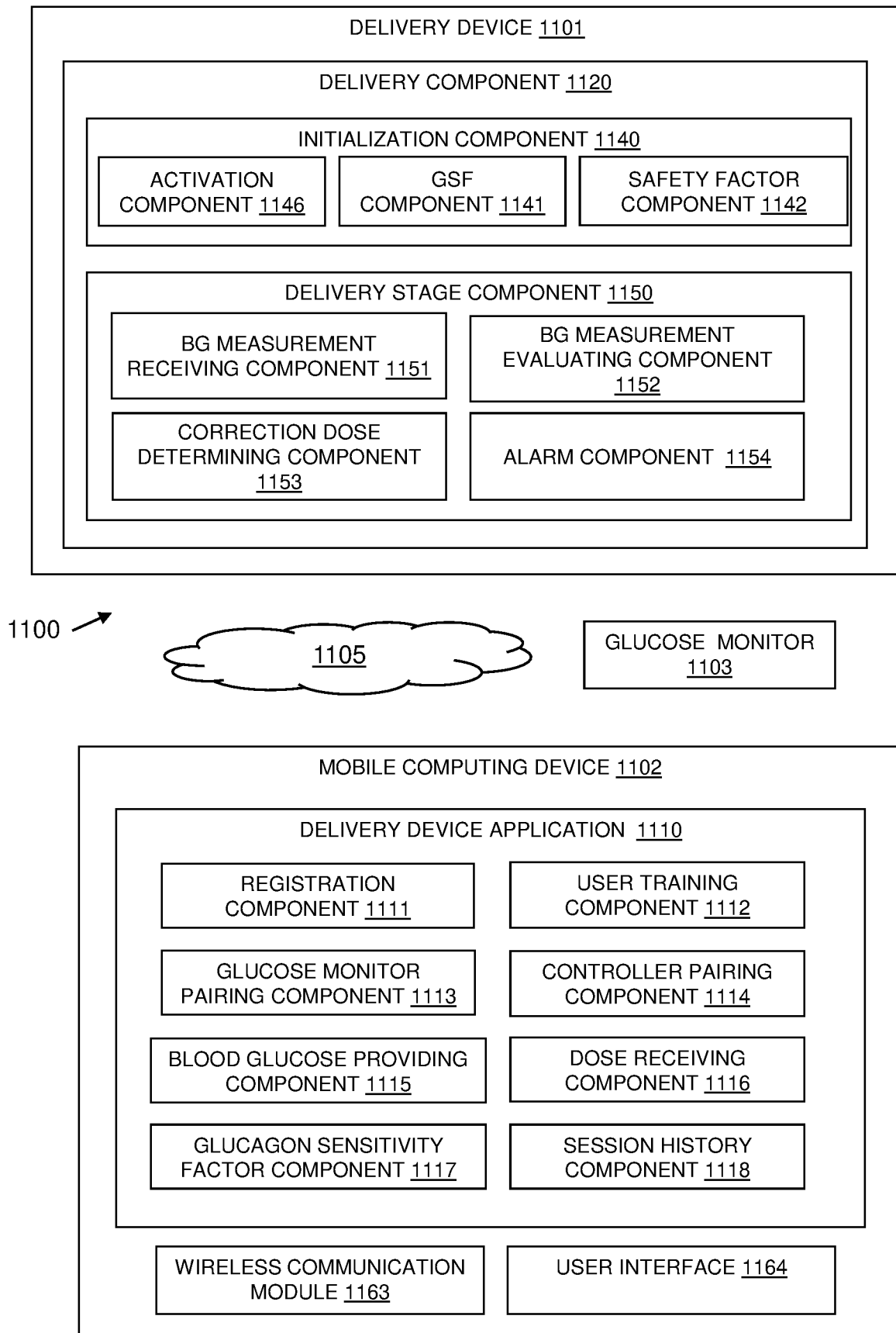
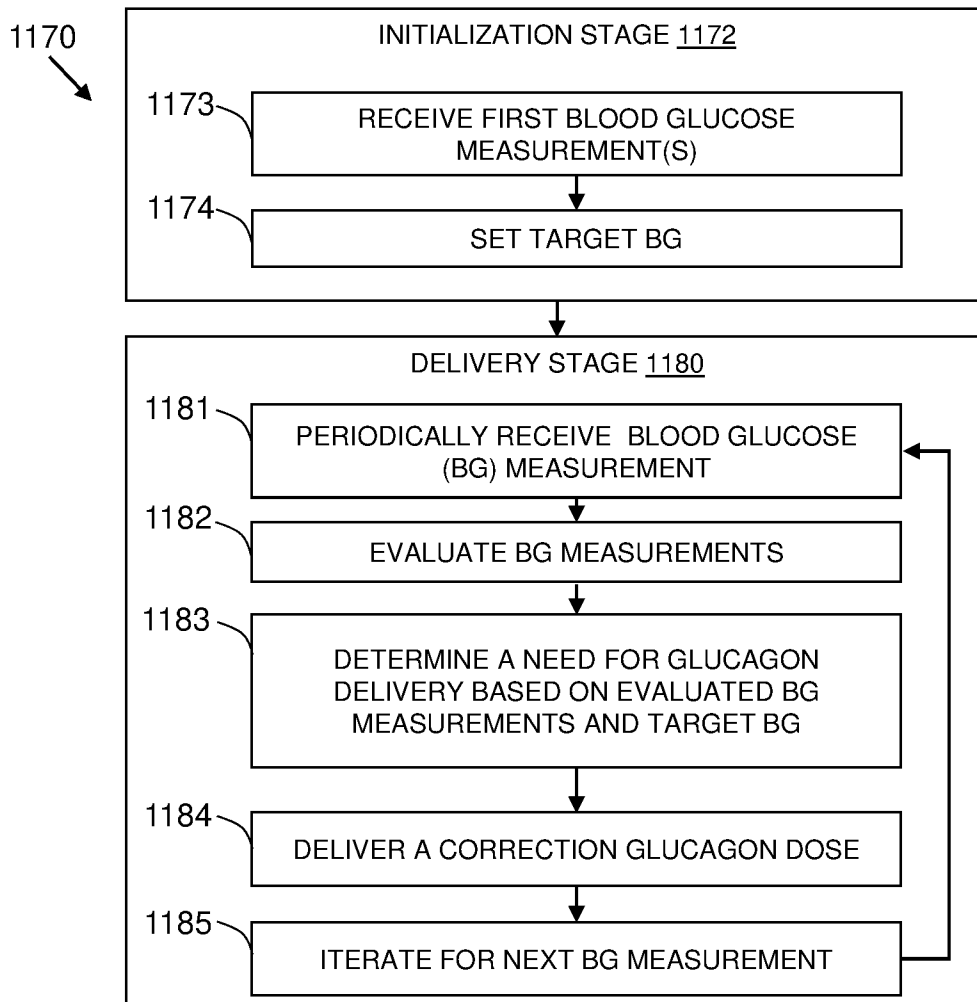
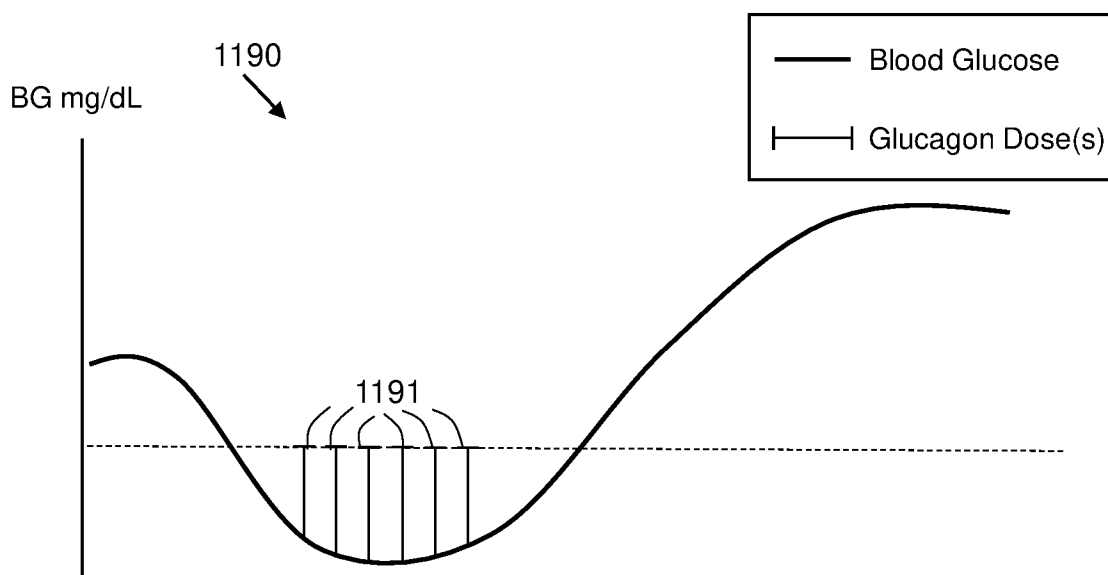


FIG. 11A

**FIG. 11B****FIG. 11C**

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2023/053950

A. CLASSIFICATION OF SUBJECT MATTER

INV. **G16H20/17** **G16H40/63** **G16H20/60**
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G16H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021/098105 A1 (LEE JOON BOK [US] ET AL) 1 April 2021 (2021-04-01) paragraph [0002] paragraph [0016] paragraph [0025] - paragraph [0033] paragraph [0045] - paragraph [0048] paragraph [0054] paragraph [0075] paragraph [0104] paragraph [0113] - paragraph [0114] ----- -/--	1-49



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

27 June 2023

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2

NL - 2280 HV Rijswijk

Tel. (+31-70) 340-2040,

Fax: (+31-70) 340-3016

Authorized officer

Gardiner, Alexander

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2023/053950

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GEORGE GRUNBERGER ET AL: "Consensus Statement by the American Association of Clinical Endocrinologists/American College of Endocrinology Insulin Pump Management Task Force", ENDOCRINE PRACTICE, vol. 20, no. 5, 1 May 2014 (2014-05-01), pages 463-489, XP055425648, US ISSN: 1530-891X, DOI: 10.4158/EP14145.PS page 480; table 2 -----	1-49
A	GARNICA O ET AL: "Noise spectral analysis and error estimation of continuous glucose monitors under real-life conditions of diabetes patients", BIOMEDICAL SIGNAL PROCESSING AND CONTROL, ELSEVIER, AMSTERDAM, NL, vol. 61, 27 June 2020 (2020-06-27), XP086220465, ISSN: 1746-8094, DOI: 10.1016/J.BSPC.2020.101934 [retrieved on 2020-06-27] the whole document -----	1-49

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2023/053950

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		CA 3150460 A1	01-04-2021
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