# A novel use of wearable technology and artificial intelligence to advance treatment in Anorexia Nervosa


## Abstract

The potential of "e-health" interventions in Anorexia Nervosa has been recognized over the past two decades, with a growing roster of apps, online resources and wearable technology. Recently, adoption of glucose sensing devices, developed for use in diabetes treatment, has opened the door for a plethora of new possibilities for Anorexia e-health delivery. This essay will outline how a novel feedback system, using glucose sensing coupled with artificial intelligence and integrated into a mobile app, could be the answer to effective and real time implementation of dietary interventions in Anorexia Nervosa patients in a variety of settings.


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## Introduction

Anorexia Nervosa (AN) is a complex and debilitating eating disorder with some of the worst morbidity and mortality outcomes in psychiatry[1]. AN can be particularly difficult to treat due to the powerful psychological maintaining factors centered around ideals of thinness, drive for lowering bodyweight and subsequent reactionary behaviors[2,3]. Typically, this may include aggressive restriction of calories, excessive exercise, purging or pharmaceutical abuse; with the outcome of rapid weight loss or low BMI [4]. Without effective management, AN has a tendency to a chronic, treatment refractory course[5].

Due to factors which include stigma, perceived benefits of the disorder and skepticism of services, AN patients are less likely to engage with care than those with physical health conditions, or other psychiatric illnesses[6]. AN interventions typically centre around weight restoration through calorie counting protocols and diet re-introduction[7]. Patients are required to adhere to mealtime schedules as inpatients or strict calorie targets in intensive day care or outpatient settings[8,9]. These interventions frequently fail to create lasting change, even with close supervision[10]. Calorie counting, along with choice of macronutrients is a labour-intensive process, especially for AN patients without supportive care givers[11,12]. Furthermore, covert purging behaviour, additional exercise and false calorie reporting is difficult to detect and can provoke confrontation between patient and care givers[13,14].

Clinicians are turning to digital technology ("e-health") for new ideas to improve patient experience and outcomes[15,16,17]. When used alongside traditional services, e-health shows promise and can be delivered via online courses, video-conferencing, text/email communication, mobile applications ('apps'), virtual reality and increasingly, artificial intelligence (AI)[18,19]. If deployed correctly, e-health can reduce pressure on existing services and provide easy accumulation of data throughout a patient's unique recovery journey.

Wearable technology as part of an e-health approach could prove to be a useful tool in AN treatment, providing opportunities for both patient and clinician. Germain et al, have shown how continuous glucose monitoring devices (CGM) can be used to study the pattern of glycaemic regulation in anorexic patients, with no examples of patient noncompliance with the device[20].

Building on Germain et al's study, this essay explores coupling CGM, with artificial intelligence and a mobile app to provide a new tool to facilitate dietary reintroduction in AN. This technology could create real time feedback on a patient's eating patterns as well as correctly flagging instances of purging and fraudulent self-report.

Wearable CGM in AN

CGM has proved to be a successful feature of diabetes outpatient management[21]. Traditionally coupled to insulin delivery, the use of these devices for purely glucose sensing was employed by Germain et al in anorexic patients, after they identified the lack of diurnal measurement of glycaemic status in AN research. Blood glucose (BM) measurement has been used up until this point only as a point of care test in severe AN physical decompensation[22].

Their findings are striking. Not only did they identify that glucose levels are lower for longer periods of the day compared to previous data on healthy controls, they also suggest that CGM devices could be used to record *actual* calorific intake compared to *self-reported* intake. By plotting post prandial glucose deltas, and correlating them to calories consumed, this technology could flag up any false reporting of calorie intake and/or post prandial purging.

Advances in CGM technology suggest that the devices will be well tolerated by AN patients. Apple Inc is poised to launch a new version of its Apple Watch which will include a completely non-invasive CGM feature[23]. Such a device can be worn for months at a time with few if any risks of complications[24]. Such a device could potentially create accountability for patients with respect to self-reporting of calories, an issue which has plagued dietary interventions throughout the history of AN, particularly in outpatient settings[25].

Combining Glucose sensing with AI in a mobile app; A unified feedback system

Measuring glycaemic patterns in AN patients using CGM is an exciting strategy however it is likely to fail without a complementary platform which can integrate BM data and calorie intake to give a digital readout of adherence to the relevant parties. Mobile apps could provide such a platform.

Apps are an example of a technology readily accessible to most ED patients and carers, and integration of mobile apps into the AN pathway is not a wholly new phenomenon[26,27]. However it is of note that most studies focus on relapse prevention rather than the acute treatment phase[28]. Notwithstanding, user feedback on apps reinforces that they are highly acceptable to AN patients, and therefore represent an ideal hub for centralization of calorie and BM data; creating a de-facto feedback system (*Figure 1*)[29].

The other role of the app is to serve as the interface for the recording of calorie intake. This can be best served through some recent advances in *artificial intelligence* technology. AI has been attempted already in ED with forays into chatbot programmes, with disappointing results[30,31]. However despite these setbacks, the use of AI does not have to be limited to these functions.

AI software from providers such as SnapCalorie, along with various copycats, is now capable of calorie counting meals based only from photographs of the plate of food[32]. Whilst still in its infancy, this AI calorie counting software has already been shown to give a reasonable fidelity in predicting calorie content for a variety of common meals and foodstuffs[33].

This type of instant data may initially appear dangerous for AN patients with highly charged beliefs surrounding food, however in fact, conversion of calorie data from photographs may have the opposite effect and help to reduce the workload of calorie counting for both the patient and care-givers. Simple adjustments to this technology could allow patients and clinical teams with the option to hide or present quantitative data on calories according to individual patient preference and their stage of recovery. For example, presenting calorie content in discrete categories (“low, medium, high”) instead of continuous data could be beneficial to certain patients. Personalisation of the app to

individuals is also consistently listed as a desirable quality and could promote patient goal setting and adherence[34,35]. The quantitative data could then be made accessible to the clinician as needed.

Photography may further have the added benefit of giving the carers and clinical teams evidence of the type of foodstuffs AN patients are consuming, and identify early any detrimental patterns or facilitate dietician led adjustment to macro or micro nutrients.

*Figure 1* provides a diagrammatical view of how these three techniques, BM sensing, mobile app and AI could combine to create a new digital feedback system. Clinical teams and patients agree to a dietary intervention, and patients will be able to passively evidence their adherence to the diet with photography and measurements of glycaemic patterns following calorie intake. Conversely, abnormal glycaemic measurements or absent photographic evidence would alert clinicians and caregivers to harmful purging or false self reporting of dietary intake, with the added advantage that regular BM sensing could also identify dangerous levels of hypoglycaemia and therefore those in need of medical stabilisation.

A system which is built on accountability between patient and clinician could drive better trust and limit the use of coercive and forced re-feeding practices.

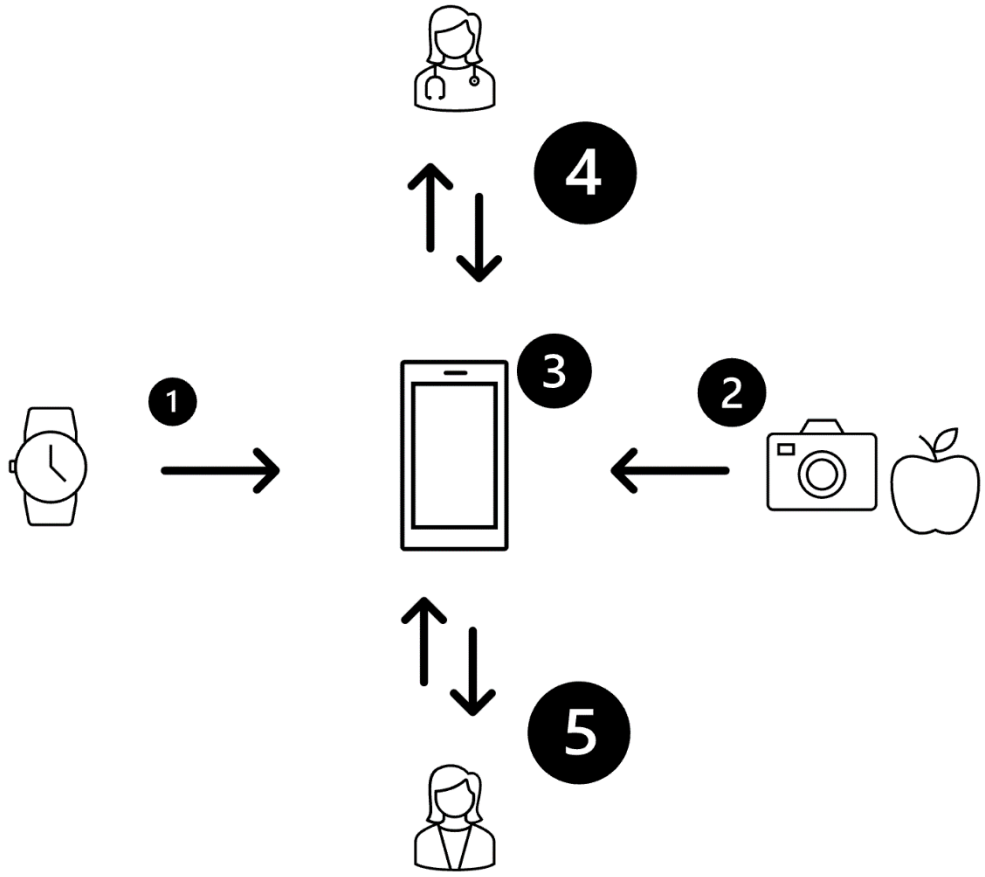


*Figure 1; Feedback system for AN dietary treatment*
*Data from wearable BM sensing devices (1) integrates with accurate calorie data generated by AI (2) to give an account of actual calorie intake vs. self-reported using an app (3). The app can communicate with clinicians and patients alike (4 & 5) to give real time feedback on adherence to dietary interventions*

Limitations of the proposed technology

The feedback model proposed in *Figure 1* is at this stage only a view of how to combine pre-existing techniques in new ways. It is important to note that the likely target population for this feedback system would be either inpatients under close supervision with 24 hour support or outpatients at an appropriate stage of recovery.

This is because AN cohorts frequently present challenges not seen in other study groups[36,37]. AN patients typically have higher rates of noncompliance, drop out and fraudulent self-report than almost any other psychiatric disorder[38,39,40,41]. The psychological drivers of the condition are often so strong that wearable technology, when combined with real time tracking, could even exacerbate the condition[42]. Furthermore, the presentation of any data collected must be handled sensitively to avoid similarly exacerbating pre-existing beliefs or creating power imbalance in the therapeutic relationship.

Despite these limitations, we should consider the likelihood that when coupling CGM with smart apps it will be much more difficult for AN patients to enact compensatory behaviours, driving open dialogue with their clinicians; drop outs will be easily identifiable. Close contact with a member of the parent team through the app could also be employed to readily identify patients who are struggling with the technology, in a similar manner to other mental health apps[43].

More generally, the author recognises that apps are not immune from all manner of retention issues common to many e-health modalities, such as user dissatisfaction, lack of personalization, bug and glitching issues, technological illiteracy and lack of human connection[44].

Despite this, we can take encouragement from user led feedback of previous e-health interventions that the use of apps is highly acceptable to most ED patients[45]. Furthermore, apps lend themselves well to other recordable features of qualitative experience, so additional arms could be added to the app which allow patients to self-journal their own experiences of the feedback system, along with positive affirmation either from the app or parent team following successful adherence to the dietary regimen.

Future directions

Following the recent Apple Inc announcement of the use of BM sensing technology into their new apple wristwatch, it seems inevitable that diurnal and nocturnal variation in glucose will become yet another health metric to capture the public conscience[46]. No doubt this will similarly capture the attention of the ED world.

When it arrives, this should propel a new series of research into the use of glucose control at all stages of AN screening, treatment and recovery. Furthermore, the eating disorders field must be ready for another potential point of focus for vulnerable teenagers and adults and have experience with the technology well in advance before these patients appear in clinics and outpatient services fixated on glycaemic control. Why not embrace these metrics for treatment and be proactive with our approach to increasingly heterogenous health technology?

Conclusion

This essay has presented a potential new model for delivering dietary interventions in AN. The case has been made to combine AI based nutrition calculations, with wearable CGM technology to ensure patient adherence to dietary protocols and detect the use of purging behaviours early in the treatment phase. Pooling this data into an app will allow multidisciplinary team tracking of calorie intake and

easy recording of macro and micro nutrient profiles, as well as providing real time feedback on adherence.

In this way, it is hoped that mutual treatment goals and trust can be generated between the clinician and patient, leading to better shared decision making and continuity of care in inpatient and outpatient settings.

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