ADAMiLO: Automated Diet and Activity Monitoring for Intelligent Lifestyle Optimisation

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"Unhealthy diets and decreasing levels of physical activity are among the leading causes of the major non-communicable diseases, including cardiovascular disease, type 2 diabetes and certain types of cancer, and thus contribute substantially to the global burden of disease, death and disability."

–World Health Organization

Digital Health and the Internet offer new opportunities in addressing these key risk factors (poor diet and physical inactivity). However, user compliance and adherence with current diet and exercise management apps are generally poor, as these apps require an extensive deal of thorough manual inputting, logging and (often inaccurate/incomplete) estimation of daily food and drink intake and activity/exercise types/duration undertaken by users.

Screenshots from a health and fitness title (Nutrition Matters, 2009) designed for the Nintendo Wii game console. Despite the interface's novelty, users are still faced with the tedious task of having to manually input their diet and activity details (food items and types of activities undertaken) by repeatedly going through hundreds of menus, submenus and options in the programme. Users need to remember and accurately describe all details (not always possible), including providing reliable estimates of food portion sizes and of durations of various exercise activities they undertook. Long term compliance is often poor with such programmes that require manual logging of diet and activity details whether on paper or digitally, and the process is not very friendly or fast enough when a user just wants to check the composition and calories in a particular meal portion in front of them before starting to eat in order to identify and avoid unhealthy meals and ingredients.
This (manual) approach is **not sustainable** in the long run as a permanent-use solution, and users tend to give up after some time. Also, the quality of the advice given by these apps is always dependent on users having correctly and fully entered all the requested details (which cannot be guaranteed).

**ADAMILO (Automated Diet and Activity Monitoring for Intelligent Lifestyle Optimisation)** has been conceived as a one-stop comprehensive P4 (predictive, preventive, personalised and participatory [person-centred]) precision health solution, integrating almost fully automated (but still very reliable and accurate) calorie composition and intake (ingested foods and drinks) and calorie expenditure (activity) monitoring and logging with intelligent cloud-based decision support (DSS) for lifestyle (diet and exercise) optimisation, that can be used by a layperson on his/her own and is tailored per individual needs, age, comorbidity, etc. The DSS acts on **real-time user data**, covering diet, activity, body weight, blood pressure, and other parameters. 

http://dx.doi.org/10.13140/RG.2.1.2907.5680
**Objective 1.** ADAMILLO aims to develop a unique IoT (Internet of Things or Internet of Food) hand-held food scanning device or smartphone attachment connected wirelessly to ADAMILLO’s specialised smartphone app component for diet composition and volume (portion size) recognition and for ingested calorie estimation, *integrating and triangulating (for the first time ever under one service)*, among other existing commercial and pre-commercial techniques:

(i) A smartphone **NIR (Near Infrared) spectroscopy** food composition scanner linked to a cloud database of food spectra (serving as ‘SHAZAM’ for food and drink items);

(ii) An advanced **machine-vision-based food volume/portion size calculation** algorithm using camera in hand-held scanner and/or smartphone camera (an optional **wireless plate weighing scale** can be added here). Used with (i) above, we can then compute the total number of calories, and actual grams of sugar, saturates, salt, etc. in a given meal (rather than per 100gms);

(iii) **Barcode scanning** for known commercial food and drink items, e.g., a Mars chocolate bar, giving exact bar weight, composition and calories from a good quality (crowdsourced/cloud-based) lookup database of barcodes of commercial food items and all their variants/packaging sizes (each variant will usually have a unique barcode); and

(iv) The following additional features: The crowdsourced cloud databases (spectra and barcodes) will grow over time to include non-European foods and drinks, e.g., Middle-Eastern, Indian and Chinese, as these are increasingly imported to the West, with specialised ethnic food restaurants also opening in many European cities and people travelling to these regions for tourism or longer stay for other purposes. The hand-held scanning device/app will have buttons (in software) to enable user to add key information. For example, a button to scan a plate prior to starting to eat and another button to scan what is left in the plate after eating (not all people finish all what is on their plate; the calories ingested will be: [all food/drink before eating/drinking -minus food/drink left after eating/drinking]). A numeric pad (in software) can allow users to enter how many of a scanned item, e.g., cereal bars, they are going to eat (or could not eat, at the end of a meal).

**Objective 2.** To develop a unique IoT activity tracking wearable and associated sensors for the detection, segmentation and quantification of exercise and quantification of calories burned by the user. The wearable will connect wirelessly to ADAMILLO’s specialised smartphone app component for real-time activity tracking, triangulating wearable and smartphone sensor data from GPS (Global Positioning System), pedometer/accelerometer, external temperature/weather, galvanic skin response and heart rate. Additional wireless sensors (need not all be part of the wearable) will also be used such as **muscle strength sensor** (to monitor user’s fitness progress), blood pressure meter and electronic body weight scale. Mobile ‘indirect calorimetry’ will be optionally used to further calibrate and increase the accuracy of the quantification of total calories burned per individual user. **Indirect calorimetry** will also be used during development, as the gold standard for benchmarking and optimising ADAMILLO’s activity tracking and energy expenditure algorithms.
Objective 3. To develop a cloud-powered decision support component (DSS) interfacing with ADAMILO's app on user's smartphone (also interfacing with an optional Jibo mini-robot coach) to help users achieve and maintain an ideal body weight and generally healthy lifestyle, particularly regarding food and its composition and exercise. The DSS will inform users regarding their calorie intake and composition (e.g., saturates, salt, etc. per day) vs. their calorie burning/expenditure balance. ADAMILO’s mobile app (decision support component interfacing with the cloud DSS) will spot and suggest appropriate, individual-user-tailored ways of rectifying any identified issues or unhealthy patterns using the latest available best medical, dietetics and exercise science evidence and existing, validated, computer/digital clinical predictive risks models and algorithms, compiled from trustworthy medical literature and established guidelines.

The DSS via the smartphone app will monitor and predict any relevant clinical risks and/or unfolding and future complications based on user’s current diet and activity and other (e.g., blood pressure) sensor readings and patterns, as well as known individual patient characteristics/clinical profile. The DSS via the app will then respond by prescribing (and presenting in an attractive and motivating way to the user) appropriate, personalised prevention or mitigation plans, e.g., to delay onset of clinical diabetes in pre-diabetes or help control hypertension, consisting of diet and exercise modifications that are tailored to patient condition and preferences and are also flexible ('user negotiable'), e.g., suggest healthier but also affordable (within a price range selected by user) food choices, nearby healthy food outlets (using GPS/location services on the smartphone) and interesting meal recipes/variations and alternatives where applicable or requested by user ('supermarket shopping companion'). (Dynamic Diet algorithms [developed by MeTeDa srl, Italy] enable the dynamic prescription of healthy alternative and equivalent diet options [food items and portion sizes], according to user’s preferences, while maintaining the original prescribed nutritional goal unchanged. ADAMILO’s automation of the assessment of a meal’s food composition and quantity will help users verify if they have correctly observed the negotiated and agreed diet modifications.)

The DSS working via the app will also continuously update the patient about their risk levels, e.g., decreasing risk levels following successful lifestyle modifications. Thanks to NIR spectroscopy, ADAMILO will additionally be able to monitor and advise users about any essential ingredients lacking in their diet (under-nutrition) and their intake of substances with cumulative toxicity in daily food (e.g., mercury in canned tuna), so that they can always stay within the recommended limits. Users will also be warned regarding allergens or any other food intolerances in food they are about to ingest, based on their known medical history of such conditions (e.g., lactose intolerance, gluten sensitivity, peanut allergy, etc.).

‘Measured doses of calorie burning via exercise’ will be prescribed in the form of tailored physical activities/exercise regimes, custom workouts, digital exergames, etc. as necessary. The nature, type(s) and amounts of exercise will be determined based on not just users’ BMI, current calorie intake and expenditure/activity patterns, but also their general health condition and other individual requirements such as hip/knee joint issues, old age and frailty, pollen allergy (workout routes prescribed based on latest pollen forecasts and where needed alternative routes are suggested), etc.
Objective 4. To involve a heterogeneous sample of EU populations in the design/development and testing/evaluation of ADAMILO via different sites across Europe representing populations north and south of Europe (e.g., Scotland UK, Denmark, Spain and Greece in the original ADAMILO proposal) and spanning a good range of user characteristics, local cuisines/food products in supermarkets (e.g., Greek/Mediterranean diet vs. Danish diet), dietary and physical activity habits/customs, and age groups (young, middle aged and older people). Healthy people will be included, in addition to patients with one or more of the following: overweight, morbid obesity, select clinical complications/conditions in which obesity is a prominent risk factor, select cardiometabolic conditions and risk factors, such as metabolic syndrome, dyslipidaemias (certain types), insulin resistance/pre-diabetes and mild to moderate hypertension, in which diet and activity play important roles in aetiology/pathogenesis as well as treatment/overall management and prevention, and in which a lifestyle optimisation DSS can be used by lay patients on their own without an attending clinician 'in the loop'.

Objective 5. To carefully consider and where applicable address horizontal and cross-cutting issues related to the success and sustainability of ADAMILO in non-technical user environments and its ultimate market viability as a real-world, mainstream consumer solution beyond the current project duration. Specifically, the project team will investigate a range of critical horizontal issues, including possible linkages to EHR (Electronic Health Records), cloud privacy/security issues, ergonomics and interface usability/user-friendliness for ordinary lay people, standards (e.g., Continua Health Alliance Kitemarking guidelines, HL7’s Fast Healthcare Interoperability Resources [FHIR], etc.) for future expandability, regulatory compliance and certification, e.g., CE marking (important for future commercialisation) and suitable business model(s) for exploitation.
• Adequate and **representative user involvement** in design iterations and evaluation
• Ergonomics and interface **usability/user-friendliness** for ordinary lay people
• Peer-to-peer support and **lasting positive behaviour and lifestyle changes**
• **Service sustainability** in non-technical user environments
• **Market viability** as a real-world, mainstream consumer solution
• **Business model(s)** for exploitation
• **Linkages to EHR** (Electronic Health Records)
• Cloud **privacy and security**
• **Standards**, future expandability and interoperability, **regulatory compliance and certification**
• **ADAMILO as an open ecosystem supporting third-party add-ons and apps** in ADAMILO Store or Marketplace: additional functions developed by third parties, e.g., extra digital games and exergames, extra sensors for niche health conditions, etc., using ADAMILO’s **API**—Application Programming Interface
ADAMILO smartphone app: putting the user in the driver’s seat
Predictive, preventive, personalised, clinical-evidence-based and precise


WP3: Existing Clinical Risk Prediction Models/Algorithms for User Risks
Prediction: e.g., Framingham Risk Score, PAHO, SCORE Index, CORE Index etc.
Clinical risks classification of users: prediction of cardio-metabolic risk will be based on information/data on aetiological factors (e.g., birth weight, growth rates, etc.); socio-demographic indices (e.g., age [old age poses different issues], sex, educational level); lifestyle indices (e.g., smoking habits, alcohol consumption habits, etc.); anthropometric indices (e.g., Body Mass Index and waist circumference); and medical history and use of medication (e.g., for pre-hypertension or hypertension, dyslipidemias, insulin resistance AND/OR blood pressure levels as well as total cholesterol, HDL-cholesterol, triglycerides, fasting glucose and HbA1c levels, if available from recent biochemical screening).

Low Risk Group
Moderate Risk Group
High Risk Group

WP2: Clinical Evidence for ILO DSS
Recommendations using a S.M.A.R.T. (Specific, Measurable, Achievable, Realistic, Time-oriented) goal setting approach.

N.B. WP2 and 3 (shown in this diagram) focus on the clinical foundations of ADAMilo and feed into the technical Workpackages. The later, namely WP4, 5, 6, 7 and 8, deal with the actual technical implementation of the real-time ADAM monitoring and ILO DSS components of ADAMilo.

WP2: Clinical Knowledge to reason with real-time user information on:
- Dietary intake (i.e., total daily energy and nutrients' intake and food consumption patterns);
- Physical activity levels;
- Resting metabolic rate;
- Body weight, blood pressure, muscle strength;
- Motivation to change, self-efficacy, etc.

As well as individual user profile: A possible range of relevant concurrent health issues / medical history, such as food allergy or intolerances, hip/knee joint disease, frailty syndrome in old age, osteoporosis, etc., that must also be considered when applying clinical knowledge to formulate personalised diet and exercise recommendations.

Initial clinical risk levels will then be monitored and continuously updated as the user’s condition progresses and/or the ILO DSS lifestyle recommendations are adopted and practised by the individual.
Progressing from mere automated identification of food and drinks to an application which can reason with identified items to better assist users

User’s real-time lifestyle data (automated diet and physical activity monitoring for enhanced compliance/adherence, body weight, muscle strength, blood pressure)

Existing validated computer/digital clinical predictive risk models (WP3)

Clinical, dietetics and exercise science evidence and layperson education for lifestyle management (WP2)*

*Established evidence and guidelines needed to translate computer model decisions (predictive risk formulae and scores from existing computer models in WP3) into preventative lifestyle actions and the education needed to make those actions realisable and sustainable by users

WP5 Classification Engine (ILO DSS)
- Real-time lifestyle data/patterns evaluated based on WP2 evidence for normal ranges/patterns and thresholds (e.g., using Arden syntax)
- User’s clinical risk levels predicted and updated using the integrated and adapted existing computer models from WP3

WP5 Recommendation Engine (ILO DSS)
- Personalised lifestyle recommendations (actions) and tailored education prescribed, delivered and their implementation by the user monitored

Existing validated METEDA Dynamic Diet computer clinical/dietetics algorithms will be used to add flexibility to the prescribed lifestyle actions and enable the user to negotiate them, thus further enhancing user’s compliance and adherence

Additional optional interfaces and features to support a sustainable positive health behaviour change and further enhance user’s compliance and adherence, e.g., social digital games/exergames (facilitated by WP5’s Event Organiser within the User Profiles and Social Networking cloud-based components of ADAMILO) and a mini-robot (Jibo) coaching interface.

Towards an “Internet of Food”: Food Ontologies for the Internet of Things

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http://dx.doi.org/10.3390/fi7040372
Individualised, flexible and negotiable recommendations = better compliance and long-term adherence

ADAMILO's integrated Dynamic Diet algorithms (MeTeDa srl team, Italy)

Patient can opt for alternative equivalent food items...

ADAMILO automates the assessment of food composition and quantities of the different food items in a meal to ensure the updated meal composition and item quantities are well observed and that the original prescribed nutritional goal is still maintained and well adhered to.

The algorithms re-calculate and adjust the portion of the other food items in the prescribed diet to restore the prescribed nutritional goal.

The new portion size of the second food item is recalculated (now smaller) to compensate for the change (increase) in the portion size of the previous food item.
Verifood SCiO (Consumer Physics, Israel), a partner in ADAMILO's Consortium, has developed unique technology for non-destructive and contactless analysis of various substances. This technology comprises low-power and low-cost miniature spectrometer, the size of smartphone camera, and associated algorithms. Support for non-homogeneous food is expected to be refined over the project duration.
**Accuracy and precision (Cont’d)**

Mobile 'indirect calorimetry' (COSMED team, Italy) will be used as the gold standard for benchmarking and optimising ADAMILO's activity tracking and energy expenditure algorithms, and will also be optionally used to further calibrate and increase the accuracy of the quantification of total calories burned per individual user (e.g., as metabolism slows down with dieting).

- **Smart triangulation** of different wearable sensors for automated cardiovascular fitness and physical activity type (e.g., walking, cycling, swimming, etc.) recognition and quantification (Fraunhofer Portugal team, Portugal).
- ADAMILO's **muscle strength sensor** to monitor user's fitness progress (NUIG team, Ireland).
Rather than using generic self-efficacy scales, ADAMILO will use health-specific specialised self-efficacy scales translated to user's language, namely the Nutrition Self-Efficacy scale, the Physical Exercise Self-Efficacy scale, and, for certain users with alcohol-related problems, the Alcohol Resistance Self-Efficacy scale. These scales have been developed and validated by Ralf Schwarzer and Britta Renner at the Freie Universität Berlin (http://userpage.fu-berlin.de/~health/healself.pdf). The scales will be offered to the users within the ADAMILO smartphone app, as part of the user profile data gathered by the app. Besides using them for evaluation in WP9 (as a 'before/after' measure), progress on these important scales will be fed back to the users and also used in further personalising and tweaking ADAMILO's recommendations and their presentation to the user as appropriate.
More possibilities...

Further future initial profiling and classification of enrolled patients with obesity according to their gut hormone levels, genetic makeup (cf. IBM Watson's approach*), etc., with the ILO DSS taking this knowledge into consideration when recommending a personalised diet; additional future sensors (e.g., a portable blood lipid measuring sensor, a glucometer, etc.); additional functions developed by third parties; etc.

*Integrating ADAMILO's vision with other emerging precision medicine and health developments that utilise cognitive computing such as IBM Watson to factor a person's genetic makeup into diet and exercise recommendations:

IBM Watson ups the ante on digital wellness with gene-based health app

At the 2016 CES, IBM Watson and Pathway Genomics unveiled a new health app that takes the user's genes into account.

By Conner Forrest | January 7, 2016, 11:05 AM PST

As the app helps build out a diet plan for users, it takes a look at the genetic variants that determine how the user burns fat, or how quickly he or she will feel full after eating. The app also relies on this information when making restaurant recommendations.

PHC-28-2015 - Number of proposals submitted (April 2015): 184 (ADAMILO was one of them); of them 31 came above ESR threshold.

**Available budget for PHC-28-2015 topic (M€): 19.5** (enough to fund only 4-6 projects). (The Commission considered that proposals requesting a contribution from the EU of between EUR 3 and 5 million would allow this specific challenge to be addressed appropriately.)

**Success rate for submissions under PHC-28-2015: ~2.7% (5/184)** — ADAMILO’s ESR:

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**Evaluation Summary Report**

**Evaluation Result**

Total score: 11.50 (Threshold: 12)

**Criterion 1 - Excellence**

Score: 4.00 (Threshold: 4/5.00 , Weight: 100.00%)

**Criterion 2 - Impact**

Score: 4.00 (Threshold: 4/5.00 , Weight: 100.00%)

**Criterion 3 - Quality and efficiency of the implementation**

Score: 3.50 (Threshold: 3/5.00 , Weight: 100.00%)

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“well below counterparts in the US, with the National Science Foundation success rate standing at 22-24% and the National Institutes of Health at 18-21%. Even in Australia, where public R&D funding has been cut, applicants to the National Health and Medical Research Council have a 21% chance of success.”

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See: Pennings R. How to avoid Horizon 2020 success being tarred by high failure rate. Science|Business (online), 2015 May 20


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As an Innovation and grants consultancy with 20 years’ experience in EU funding, we know that a collaborative single-stage proposal costs between €70,000 and €100,000, on average, in time and effort to develop and write.