PeRsOnalised nutriTion for hEalthy livINg: The PROTEIN project

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Abstract

Personalised nutrition is a novel public health strategy aiming to promote positive diet and lifestyle changes. Tailored dietary and physical activity advice may be more appropriate than a generalised 'one-size-fits-all' approach as it is more biologically relevant to the individual. Information and computing technology, smartphones and mobile applications have become an integral part of modern life and thereby present the opportunity for novel methods to encourage individuals to lead a healthier lifestyle. This article introduces the European Union-funded *PROTEIN* project (*PeRsOnalised nutriTion for hEalthy livINg*) consortium and introduces the associated work packages. The primary objective of the *PROTEIN* project is to produce a novel adaptable mobile application suite based on sound nutrition and physical activity advice from experts in their field, accessible to all population groups, with differing health outcomes, whose behaviour can be tracked with a variety of sensors and health hazard perception. The mobile application 'ecosystem' that will be developed by the consortium includes a platform, mobile suite, cloud services, artificial intelligence advisor, game suite, modelling of expert's knowledge, users' behaviour data collection, data analysis and a dashboard for healthcare

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professionals. It is proposed that users will find the provision of personalised nutrition advice and real-time data capture through a smartphone application useful, and importantly, will be encouraged by this to make positive health behaviour changes.

Keywords: healthy living, m-health, personalised nutrition, public health

Introduction

Currently, the lifestyle habits of the general population, both within and outside the home, have changed significantly due to the ongoing SARS-COV-2 (COVID-19) (WHO 2020) pandemic, with access to information and computing technology (ICT), smartphones and mobile applications now, more than ever, an integral part of modern life. Furthermore, many individuals have changed their daily habits towards a reliance upon online shopping as a result of, for example, 'shielding' or 'self-isolating' within the home and due to the closure of non-essential shops. Technology also offers the potential to encourage physical activity at home, particularly when recreational facilities, team sport complexes and fitness centres are closed or have reduced access during local and national lockdowns (Hudson & Sprow 2020). An example is the utilisation of wearable sensors, such as activity watches or heart rate monitors, to ensure an individual meets their weekly 150-minute moderate intensity activity target, as recommended by the UK government (Public Health England 2019).

Wearable devices now present the opportunity for the everyday user to measure variables of importance to them, such as their heart rate during different modes of exercise, blood glucose levels for people with diabetes and even the amount of time spent sleeping every night. In the US trial, *CalFit* participants used a mobile phone application to monitor their daily step count for 10 weeks. Results showed that the intervention group, who received push-notifications, had significantly higher step counts than their control counterparts (Zhou *et al.* 2018). However, the usefulness of some trackers remains disputed, not least because they are largely dependent upon the individuals' motivation and often influenced by social competition (Chiauzzi *et al.* 2015; Patel *et al.* 2015). Social competition may be used by employers as an incentive to improve employee performance; however, these strategies tend to be limited to encouraging the more

successful and may dishearten other less-competitive employees (Wang *et al.* 2018).

As non-communicable diseases, such as obesity, cardiovascular and diabetes, have been identified as risk factors for contracting the COVID-19 virus (WHO 2020), there has been a considerable mobilisation towards improving public health. Indeed, the UK's Prime Minister, Boris Johnson, has become more sensitive to addressing the rising obesity levels following his own experience of the virus (The Lancet 2020). This is relevant when, within the UK, over a quarter of adults are classified as obese (BMI >30 kg/m^2), and the figure is projected to grow (Public Health England 2020). Poor nutritional status as a result of low-quality dietary intakes within the UK is also common, with less than a third of UK adults consuming the recommended five portions of fruit and vegetables daily (NHS Digital 2020). Advances in ICT could provide a novel method of delivering practical nutrition and physical activity advice directly to the individual via m-Health (mobile health), defined by the World Health Organization (WHO) as a 'medical and public health practice supported by mobile devices' (WHO 2011).

Data from 2015 show that 88% of the population of the UK use the Internet and 68% report owning a smartphone (Pew Research Centre 2016), thereby allowing access to nutrition and physical activity advice and support that previously may have been limited to the more affluent. A great number of m-Health applications are currently available on the smartphone market: in January 2020 it was estimated that 115 750 iPhone users downloaded MyFitnessPal (Statista 2020) (UnderArmour, US) – a popular free diet-tracking mobile application. There were 1 million downloads (estimated 92% increase compared to the same time last year) of Public Health England's 'Couch to 5k' fitness mobile application from March to June 2020 (NHS England 2020). In addition to this, according to a survey conducted by the

application 'RescueTime', the average UK adult spent on average 3 hours 15 minutes each day on their smartphone in 2019 (RescueTime 2020). Therefore, the number of users of fitness and nutrition trackers would be anticipated to rise in the upcoming years as we spend more time 'on-screen', and potentially with restricted access to traditional forms of exercise where lockdown restrictions persist. These applications could provide an invaluable opportunity to deliver nutrition or physical activity interventions and to promote and monitor achievement of health-related targets through the collection of data using digital-based sensors. These sensors also confer added benefit for governing health bodies and researchers as they aid with data collection, often referred to as 'citizen science'. Citizen science is defined as the 'general public engagement in scientific research activities where citizens actively contribute to science either with their intellectual effort, or surrounding knowledge, or their tools and resources' (Follett & Strezov 2015). As a principle, it engages the public in scientific projects that could otherwise be difficult for the researchers to conduct alone, due to a lack of funding or resources. Within nutritional and sport sciences, the most commonly utilised version of 'citizen science' is contributory, where the participant contributes to data collection by wearing sensors within a free-living environment (Seshadri et al. 2019; Dimitratos et al. 2020).

Utilising m-Health could potentially improve self-monitoring, goal setting and the development of self-efficacy. However, it is unclear whether this can facilitate long-term behaviour change. In fact, results from previous literature suggest that behaviour change as a result of using m-Health is limited and positive changes could be short-lived (McKay et al. 2018). There is also a lack of regulations and defined standards for the advice provided to users by the developers and users may choose an application due to its ease of use, minimal use of push-notifications or market price rather than the accuracy of advice provided. Therefore, the protection of the customers can be overlooked by developers of m-Health applications (Ahlgren et al. 2013). Moreover, some fitness and nutrition applications are limited to certain population groups (e.g. adults with obesity, diabetes or cancer), certain ages and/or target health outcomes (e.g. weight management). Therefore, the principal aim of the PROTEIN project is to produce an adaptable mobile application suite based on sound nutrition and physical activity advice from experts in their field, accessible to a range of population groups with different health outcomes who can be tracked with an array of established and novel sensors and health hazard perception.

Personalised nutrition

Whilst there is no agreed definition of personalised nutrition (PN), Gibney et al. (2016) describe this as an approach that 'assists individuals in achieving a lasting dietary behaviour change that is beneficial for health'. Terms such as precision nutrition and nutrigenomics may be used interchangeably, although it should be noted that these only partially overlap with PN. Ordovas et al. (2018), in their review of the evidence base for PN, provide a useful comparison and description of these key terms. Within the latter review, it is highlighted that personalisation can be based upon two separate factors. Firstly, the biological evidence of responses to foods or nutrients that are dependent upon an individuals' phenotype (such as body mass or height) or genotype (such as single nucleotide polymorphisms within the DRAM1 gene; rs77694286) (Merino et al. 2019). Secondly, the analysis of individual preferences from exercise to food and the successful delivery of an intervention to incorporate these. Overall, PN plays a significant role in modern nutrition interventions as it attempts to take relevant information from the individual into account. This methodology thereby significantly contrasts to the 'one-size-fits-all' approach (Verma et al. 2018).

Evidence from the literature shows that there is considerable inter-individual variability in response to the same dietary exposure (Mathers 2019). Weight loss trials are a key example of this; a recent randomised clinical trial, referred to as the DIETFITS trial (Gardner et al. 2018) – a 12-month weight loss intervention of a healthy low-fat or low-carbohydrate diet – found that there were no significant changes in weight loss observed between the intervention groups (−5.3 and −6.0 kg, respectively). However, individual weight loss ranged from −30 to +10 kg in both groups throughout the duration of the trial, illustrating that not all restrictive diets are conducive to weight loss in different individuals in a real-world setting.

Similarly, there are marked inter-individual differences in response to dietary supplementation of micronutrients, for example, vitamin D. To prevent and combat vitamin D insufficiency or deficiency [which is common during the UK winter (SACN 2016)], supplementation is common practice. This is because our primary source of vitamin D is through direct exposure to ultra-violet B irradiation (UVB) and not through dietary intake due to limited sources

within the diet. However, in response to a given dose of vitamin D, differential effects on serum 25-hydroxyvitamin D [25(OH)D] concentrations are seen between individuals, dependent upon a multitude of factors such as ethnicity, adiposity, age, genetics, calcium intake, etc. (Mazahery & von Hurst 2015; Zhang et al. 2017). This highlights that dietary advice, including supplements, should be tailored for the individual consumer to maximise the benefits.

M-Health

M-Health presents an opportunity to provide PN advice within the home and deliver the necessary tools for an individual to change or sustain a healthy lifestyle. M-Health interventions employ different methods to interact with their users, which may include mobile-phone text messaging, personal digital assistants, web-based and smartphone applications (Free et al. 2010). These have been used across many different health sectors to provide support to different health or lifestyle conditions, such as smoking cessation (Krishna et al. 2009), sexually transmitted infection prevention/testing (Kho et al. 2006) and to support clinical practice (Kho et al. 2006). M-Health applications have been used to promote adherence to healthy living targets in the pre-conception and pregnancy period, for example, the 'Smarter Pregnancy' application (Erasmus MC, NL) (Erasmus MC 2020) coaches users and their partners via an evidence-based 26-week subscription aimed at enhancing pre-conception and pregnancy health through push messages and emails. A survey of over 1800 users showed that lifestyle behaviours that could be tracked and enhanced by the web-based m-Health coaching included folic acid use, tobacco use, alcohol consumption and fruit/vegetable intake (van Dijk et al. 2016). The authors suggest that a high compliance rate (64%) may be attributed to online anonymity, which is of high-value to end users, with tailored m-Health programmes providing a 'comfort zone' for users and thereby encouraging honesty (van Dijk et al. 2017). However, a limitation to the Smarter Pregnancy programme is that the researchers did not consider ethnicity and socioeconomic status.

The EU-funded Food4Me study (Celis-Morales et al. 2017) was one of the first randomised controlled trials to compare and contrast three different levels of PN delivered via m-Health: (1) dietary advice based on individual dietary intake; (2) dietary advice based on individual intake and phenotypic data; and finally (3) dietary advice based on intake, phenotypic and genotypic data. The individualised dietary advice was web-based and utilised an automated dietary feedback system to deliver the recommendations to their 1607 users across seven different EU countries for a total of 6 months. The main findings from this study demonstrate that PN (levels 1, 2 and 3) was more effective than a 'one-size-fits-all' population-based nutritional advice (control group). The treatment groups showed significantly higher daily fruit intake, lower salt intake, lower saturated fat intake and had a significantly higher healthy eating index than those in the control group (Guenther et al. 2013). However, it is difficult to determine whether personalised targets were achieved. This is because, as an example, there were no differences in weight or waist circumference (which were self-reported by the participants), detected between the treatment groups. Nor were any targeted health outcomes, such as blood lipid profile or glucose levels, discussed. Furthermore, this study suggested that the integration of phenotypic information alone or in combination with genotypic information did not enhance the effectiveness of the PN advice provided to the users compared with dietary advice based on just the individual dietary intake. Therefore, further evidence for the service-user-perceived usability of PN is warranted as its use is still in its infancy with respect to disease prevention and therapy (Barrea et al. 2020).

The protein consortium

The PeRsOnalised nutriTion for hEalthy livINg (PROTEIN) consortium is funded by the European Union's Horizon 2020 research and innovation programme. It comprises 20 partners from a total of 11 European countries, with partners from industry, research and technology organisations. The consortium aims to develop a new mobile application suite that will engage people to lead a healthier lifestyle by offering dietary and physical activity programmes adapted to their needs and driven by their health status, personal preferences and physiological characteristics. This will be delivered through the utilisation of modern technology, such as artificial intelligence (AI) and sensors, to capture daily life. The consortium aims to address several key objectives through a total of 10 work packages (as presented in Fig. 1) spanning a 42-month time period, from January 2019 to June 2022.

The principal aim of the project is to design a PROTEIN 'ecosystem' that includes a mobile suite, cloud services, AI advisor, game suite, modelling of expert knowledge, users' behaviour data collection, data analysis and a dashboard for healthcare professionals.
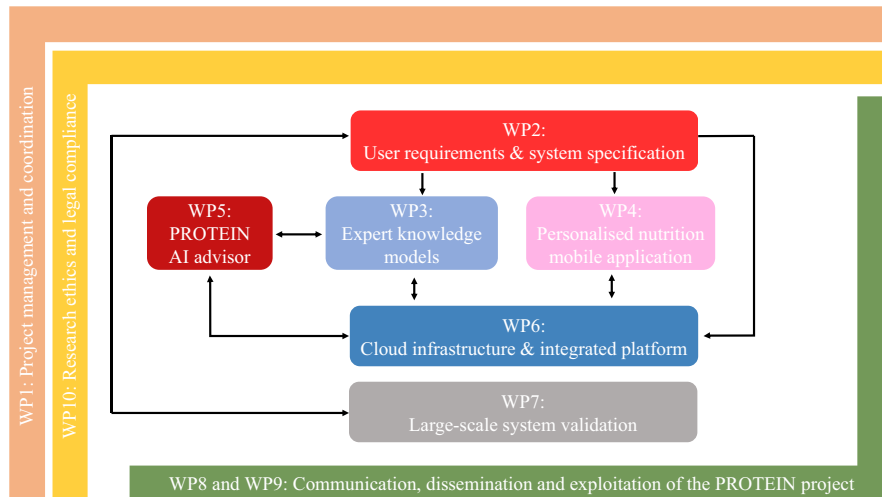
Figure 1 Interrelations between work packages [Colour figure can be viewed at wileyonlinelibrary.com]

Further objectives of the *PROTEIN* consortium are as follows:

(1) To create a model to analyse the users' dietary behaviour in correlation with their individual parameters (such as genetic information) to interpret the drivers of food preferences.
(2) To design and develop a novel personalised recommendation engine, which will consider the expert knowledge models, user preferences and their health status.
(3) To develop novel techniques for measuring dietary intake as well as to conduct pre-, post- and within-meal analysis within the *PROTEIN* 'ecosystem'.
(4) To engage users through a gamification suite to encourage healthy food choices and behaviour change.
(5) To build a *PROTEIN* platform with an open and service-orientated architecture.
(6) To validate the integrated platform in a variety of 'real-world' operational environments and collect data from a number of different user population groups through two separate pilot phases, carried out at different European institutions in Belgium, Germany, Greece, Portugal and the UK.

The following work packages are relevant to the development of key components of the *PROTEIN* project.

Work package 1: Project management and coordination

The aim of this work package is to co-ordinate the activities of planning, organising, monitoring and managing the necessary tasks. The key objectives are as follows: (1) establish an effective project governance structure; (2) establish a clear set of processes for efficient quality innovations; (3) establish an adequate set of guidelines for project leaders; and finally, (4) monitor all project work, risk assessment and management activities.

Work package 2: User requirements and system specification

This work package will focus on the user requirements and the technical specifications that will be essential to define the user scenarios that need to be developed for the overall *PROTEIN* system architecture. The system architecture is comprised of three main areas: (1) the application level, within which there are three separate user-case scenarios (to be utilised within the home, the restaurant and supermarket); (2) the 'ecosystem': comprised of the AI advisor, the *PROTEIN* cloud and healthcare professional dashboard; and finally, (3) the sensors that will provide data outputs to the application. The sensors that have been chosen for the project include a wearable smart band activity tracker (MiBand3, Google), a smart belt (currently undergoing further development, which will measure bowel movement/sounds via an acoustic sensor), a smart scale to measure food intake (Skale 2, Atomax Inc), a volatile organic compound sensor (Series-300 VOC, Gas Sensing) to measure expired air in order to assess gut microbiota composition and a continuous glucose monitor (Dexcom G6, UK).

Work package 3: Expert knowledge models

The key aim of this ongoing task is to develop a library of evidence-based, expert approved conceptual 'rules' based upon current literature and to produce a complete database of user group-specific nutrition and physical activity recommendations. Within the *PRO-TEIN* project, experts in the field of nutrition, genetics, technology, medicine and physiology collaborated to set reference ranges within which the system would operate, defined for each user group (identified in Table 1). An example of the reference ranges agreed by the experts for a physical variable is BMI (18.5–24.99 kg/m^2) or for a dietary intake variable, vitamin D (10 μg/day). The dynamic adaptation to a user's actual daily behaviour and weekly routine will be performed by the AI advisor (developed in WP5) using the data and the parameters that were set by the experts. Specific recommendations were developed through a combination of the experts' respective national recommendations for nutrition and physical activity and the EU European Food Safety Authority guidelines (EFSA) (EFSA 2017). The amalgamation of reference values was used to develop a database for macro- and micronutrient, physiological and physical activity recommendations (described in Table 2), which will be incorporated into the 'targets' provided by the AI advisor. Furthermore, this work package will generate a hierarchy of nutritional risks/notifications, which will capture certain warnings for the users. The technology team will thereby engineer a nutrition and physical activity model ontology [defined as 'a formal, explicit specification of a shared conceptualisation' (Studer *et al.* 1998)] to capture these food-to-nutrient relation rules and warnings (such as foods 'rich in', 'low in' or 'contains'), based on approved European Commission Nutrition and Health Claims [such as Regulation no 1047/2012 (European Commission 2012)].

Work package 4: Personalised nutrition mobile application

The development of the mobile application to provide the personalised nutrition advice and support to the user is the principle objective of this work package. Moreover, the mobile application will be developed to be utilised in various real-life environments, such as shopping on an online supermarket (Ocado, UK) and within a restaurant setting (Porto Fluviale SRL, Italy). The tasks that pertain to this work package include the development of sophisticated algorithms that can

Table 1 Detailed user and sub-groups for PROTEIN

User group	User sub-group
A	General public
	Healthy adults
	Healthy adolescents
	Healthy older adults
B	Under Nutritionist Supervision
	Adults who are overweight (>25 kg/m^2)
	Athletes*
C	Under Medical/Nutritionist Supervision
	Adults with obesity (>30 kg/m^2)
	Patients with type II diabetes mellitus
	Patients with cardiovascular disease
	Adults with either:
	(a) A clinical deficiency (e.g. iron deficiency anaemia)
	(b) A poor-quality diet (e.g. low fruit and vegetable intake)

*Athletes are professional footballers recruited directly by one of the partners; Benfica FC.

Table 2 Recommendations for the following parameters were developed by the experts for each user group case specified in Table 1

Diet	Anthropometrics	Physiological	Physical activity
Total energy intake (kcal)	BMI (kg/m^2)	Blood glucose (mmol/l)	Frequency (day/week)
Carbohydrate (% EI)	Waist circumference (cm)	LDL-C (mmol/l)	Duration (min)
Protein (g/kg BW)	Waist:Hip ratio	HDL-C (mmol/l)	Intensity (light/moderate/vigorous)
Fat (% EI)		TAG (mmol/l)	
Saturated fat (g)		Resting heart rate (bpm)	
N-3 fatty acid (g)		Sleep (hour/night)	
Sugar (% EI)			
Salt (g)			
Fibre (g)			
Vegetable (portion)			
Fruit (portion)			
Alcohol (g/week)			
Iron (mg)			
Calcium (mg)			
Vitamin D (μg)			
Vitamin C (mg)			

BW, bodyweight; EI, energy intake; *n*-3, omega-3; BMI, body mass index; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TAG, triacylglycerol; bpm, beats per minute.

identify foods and estimate food portions through image processing directly from the user's smartphone. Although still undergoing testing and refinement, these novel techniques for food intake identification have been recently presented by technical partners of the consortium (see Graikos *et al.* 2020 for further information). Work is ongoing to improve the performance of the food identification algorithms, including automatic calculation of the distance between the camera and plate, inclusion of more food categories, mixed-meals food recognition and enabling the estimation of liquid meals, and will be further enhanced on the basis of user feedback obtained from the pilot studies. A key component of the work package is also the integration of the sensors into the mobile application, which has so far included physical activity tracking, pre-/post-meal dynamics such as bowel movement/sound sensors and a validated within-meal automated chew counting system (Konstantinidis *et al.* 2019, 2020).

Work package 5: PROTEIN AI advisor

The main objective of this work package is to develop the nutrition and physical activity AI advisor (Fig. 2). Key components of the AI advisor that will be created include the food and activity recommender system (FARS), a reasoning-based decision support system (RDSS), a re-adaptation manager and early warning subsystems. For each user, the decision support system of the AI advisor has been developed to take the general recommendations from WP3 and to personalise them by using user profile data as well as the actual daily information collected by the sensors or manually inputted into the mobile application by the user. Figure 3 illustrates the complex system of workflows developed to date within the *PROTEIN* project.

The first version of the system is due to be released between January and April 2021 for testing within real-life scenarios within WP7. However, this will not be the final version of the system as one of the key objectives of this work package is to validate and refine the methodology of the subsystems based upon data collected during the pilot trials. For example, the re-adaptation manager will extract new knowledge on a daily basis to formalise a deep and intelligent learning system. This learning will then need to be explored by researchers to check whether the nutritional and biomedical advice is adequately provided by the system prior to releasing an updated system for the second pilot studies. Therefore, the subsystems are continuously undergoing development by the technical team of the *PROTEIN* consortium.

Work package 6: Cloud infrastructure and integrated platform

As the subsystems of the *PROTEIN* platform require a cloud infrastructure, the key objective of this work package is to set up the tools to support the internal development and operational needs of the application. Through this, the technical partners of the consortium have developed a data management system and detailed the security measures in place to protect user and within-app data generated during the pilot studies. Another key component was to develop the mobile application and web platform and to integrate the sensor technology/data.

Work package 7: Large-scale system validation

This is one of the most important work packages within the project as it evaluates the *PROTEIN* application suite as a whole through various pilot studies (potentially Jan–March 2021 and Sept–Dec 2021) across the consortium, as shown in Table 3. The key components that will be evaluated during the pilot studies include: user acceptability; effectiveness of the web/mobile services to encourage behaviour change; overall performance of the mobile suite; and security/privacy assurance. These will be evaluated through feedback received from the *PROTEIN* technical experts, nutrition/physiology experts and users of the system using evaluation questionnaires developed by the consortium and physiological data collected in user trials. Data to be collected during the pilot trials include: age, gender, anthropometrics, activity mode (low-high intensity), activity frequency (hour/day), step count, self-reported dietary intake and sleep quantity (hour/day). Furthermore, a smaller trial within the *PROTEIN* project will recruit a diverse sample of adults from user group 'C' (Table 1) to characterise their genetic profile and gut microbiome through the collection of stool and blood samples. This will contribute to the current literature and be incorporated into a more comprehensive personalised nutrition approach.

Work packages 8 & 9: Communication, dissemination and exploitation of the PROTEIN project

The principle task of these work packages is to plan, manage and carry out the project's communication activities, including dissemination and exploitation of the research and innovations. All the partners of the consortium are involved with the public engagement and communication of the results from the *PROTEIN*
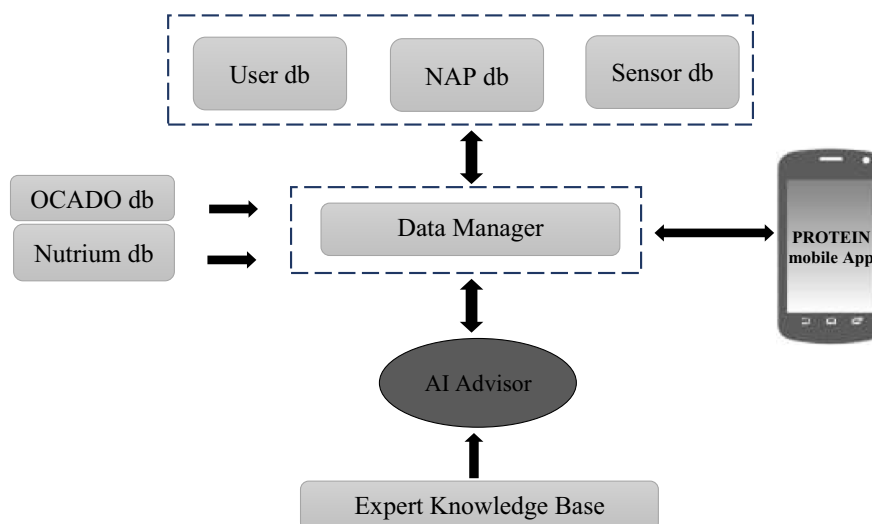
Figure 2 Overview of the first release of the PROTEIN AI advisor. AI, artificial intelligence; db, database; NAP, nutrition and physical activity plans. User db refers to the database of user-acquired data, such as their anthropometric measurements. Sensor db refers to the data captured by the respective sensors, such as from the wearable smartband (MiBand3, Google). Nutrium db refers to the existing software provided by one of the consortium members; Nutrium. This software, which enables nutrition professionals across the EU to monitor and provide remote nutritional advice, has been integrated within the PROTEIN system architecture [Colour figure can be viewed at wileyonlinelibrary.com]
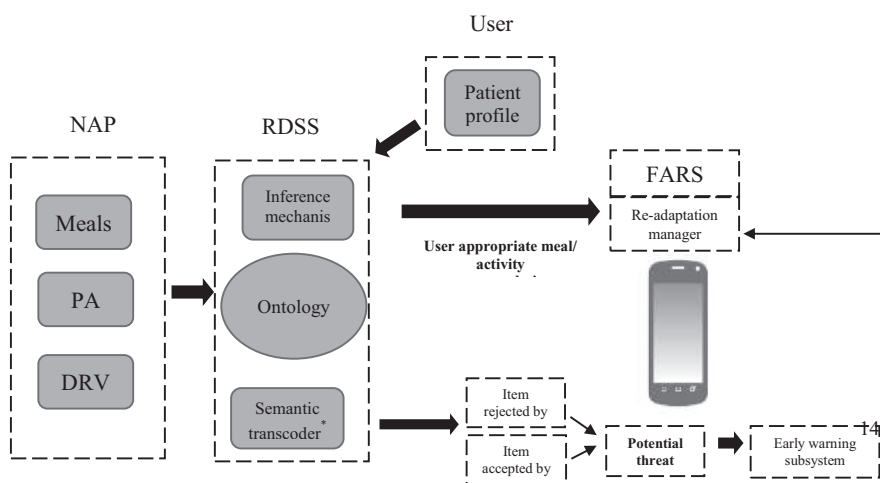

Figure 3 Diagram of the key components of the AI advisor that have been developed within WP5. db, database; DRV, dietary reference values developed by WP3; FARS, food and activity recommender system; PA, physical activity; NAP, nutrition and physical activity plans; RDSS, reasoning-based decision support system. *Semantic transcoder: this utilises work from the WP3 ontology and helps the system identify dishes, food groups, nutrients etc., such as Spinach, which is categorised/ coded as 'rich in' iron

project. This work package will last the duration of the whole project and beyond.

Work package 10: Research ethics and legal compliance

The aim of this work package is to assist the consortium during the entire project in meeting the legal and ethical requirements needed to successfully carry out the *PROTEIN* project across the 20 separate institutions and 10 different countries. This work package also includes the assessment of the system itself to identify and assess the potential risks posed by the *PROTEIN* application, such as security and adherence to the relevant data protection regulations (GDPR).

Implications for industry/practice

One of the key outputs that the *PROTEIN* project aims to provide is a system that will empower consumers to make healthy and sustainable dietary and/or lifestyle choices. It is proposed that through the

Table 3 Summary of the various pilots that will take place during the PROTEIN project

User group	Target audience	Use cases	Setting	Country
General Public	Mobile App users	Home	Mobile App	Greece
	Food retail customers	Store	Grocery and supermarkets	Italy
			Organic food supermarket	Italy
			Online supermarket	UK
	Restaurant customers	Restaurant	Restaurant	Italy
			Restaurant	Italy
			Restaurant/catering school	Italy, Lithuania
			Students	Italy
			Vulnerable population	Italy
Nutritionist Supervision	Adults who are overweight	Home	Adults who are overweight (>25 kg/m^2)	UK, Greece, Belgium
	Athletes	Home	Athletes	Greece, Portugal
Medical/Nutritionist supervision	Adults with obesity	Home	Adults who are obese (>30 kg/m^2)	Belgium, Greece
	Adults with T2DM	Home	T2DM	Germany
	Adults with CVD	Home	Adults with CVD	Belgium
	Adults with poor-quality diets/deficiencies	Home	Adults with poor-quality diet/deficiencies	UK

CVD, cardiovascular disease; T2DM, type 2 diabetes.

provision of real-time, personalised services based upon the data collected from the user, the content will be perceived to be useful and engaging for individuals from different population groups. In addition to this, the *PROTEIN* project will also provide evidence-based dietary, physiological and physical activity assessment and advice developed by experts in their field, which will be novel to the smartphone m-Health app market. By delivering this information through a mobile application, it is anticipated that access will be maximised for a range of potential users across the EU. Finally, the most important output that the *PROTEIN* project will provide is a novel dynamic application that will react to and learn from its users' actual daily behaviours.

Conclusion

Overall, the *PROTEIN* consortium aims to build a useable and accessible application ecosystem to engage individuals from different population groups across the European Union (the app will be available in seven different European languages initially) in healthy behaviours. The consortium will work collaboratively to further define the role of m-Health and how it can be harnessed to support personalised nutrition and ultimately positive lifestyle changes. This is highlighted through the consortium's deployment of novel wearable sensors, their creation of new nutrition and physical activity ontologies within the system and of unique user profile models. In addition to this, the consortium hopes to further the advances in technological sensors

and their application to nutrition through the development of the following: a bowel sound/movement 'smart band', within-meal chew/bite detection algorithms (Konstantinidis *et al*. 2019, 2020), a food identification algorithm (Theodoridis *et al*. 2020) and a food depth perception algorithm to calculate portion sizes (Graikos *et al*. 2020). Given the increase in noncommunicable diseases and rising levels of obesity within the UK, modern technology applications such as the *PROTEIN* application could be useful to provide end users with easily accessible validated tools to make positive lifestyle changes.

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Conflict of interest

The authors have no conflict of interest to disclose.

Author contributions

Saskia Wilson-Barnes and Kathryn Hart contributed to the preparation and writing of this manuscript. Susan Lanham-New, Lazaros Gymnopoulos and Vassilis Solachidis reviewed and contributed to the writing

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