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Abstract— **As pointed at LIVESTRONG.COM, Olympic weightlifters are quite possibly the strongest and most skilled lifters on earth. The ability to put nearly 300 kg over head or clean and jerk three times their bodyweight is feat of strength unmatched in other sports. While this takes years of dedicated training, diet is also critical as optimal nutrition is essential for peak performance. Nutritional misinformation can do as much harm to the ambitious athlete as good nutrition can help. In this study, we propose ontology-based personalized dietary recommendation for weightlifting to assist athletes meet their requirements. This paper describes a food and nutrition ontology working with a rule-based knowledge framework to provide specific menus for different times of the day and different training phases for the athlete's diary nutritional needs and personal preferences. The main components of this system are the food and nutrition ontology, the athletes' profiles and nutritional rules for sports athletes.**

Keywords- Ontology; Food; Nutrition; Athlete; Weightlifting.

I. INTRODUCTION

Weightlifting demands extreme strength and power to lift very heavy weights in a controlled manner. The aim of these athletes is to build muscle bulk and target the main muscles that are used for the bar movement. A high level of muscularity is therefore required by both male and female competitors. Maintaining low body fat is also a physical requirement often demanded to optimize the power to weight ratio of lifters, helping to achieve best performance. Despite requiring a high muscle mass, control of athletes weight is very important given that competitions are divided into weight-class categories [1].

Besides providing the energy for training and for its recovery, in the case of weightlifting and other strength-power sports, nutrition also promotes training adaptations, including skeletal muscle hypertrophy [2]. A summary of the reported dietary intake of adult strength-power athletes in training, regarding to macronutrient consumption, reported that weightlifters consume a greater number of daily servings of protein-rich sources when compared with other athletes. As a result, the protein intake of male weightlifters has been reported to range between 1.6 g/kg/day and 3.2 g/kg/day [3-5], which is high when compared with the recommended 1.2–1.7 g/kg/day for resistance training athletes. Furthermore, weightlifters derive approximately 40–44% of their daily energy intake from dietary fat [1-5], which is also well above the acceptable range for health and athletic performance of 20–35%. This is probably a consequence of their greater intake of protein-rich animal products.

Conversely, the reported carbohydrate intakes in weightlifters of 2.9–6.1 g/kg/day [1, 3-5] are insufficient according to the current recommended levels of 7–8 g/kg/day for athletic individuals [6]. Combined, these reports suggest that the dietary habits of male weightlifters may not yield the desired training gains and/or health benefits due to the emphasis placed on protein consumption (with high fat) at the expense of adequate carbohydrate ingestion [1].

Ontology-based personalized dietary recommendation for weightlifting is one way to help athletes meet their requirements. Some athletes are willing to follow a menu that has been created for them but many athletes do not take this approach; rather, they look to modify their current diet. With an expert system all of them will be benefited. Moreover, it can be used by not only athletes but also coaches or sport nutritionists who take charge of making a menu for athletes.

II. RELATED WORK

There are some relevant research works, such as those described in [6-9]. The research work by Fodholi et al [6] designed and developed a daily menu assistance in the context of a health control system of a population. This project uses ontology to model a nutrition needs domain, implementing a rule-based inference engine. The system is implemented as a semantic web application, where users enter abstinence foods and personal information so the system can calculate several parameters and provide an appropriate menu from database.

Cantais et al. [9] designed a food ontology for diabetes control from a nutrition viewpoint to support health care of diabetes patients. The ontology was developed based on some referenced nutrition guides for diabetes patients. The food ontology consists of 177 classes 53 properties and 632 instances. Thirteen major classes of food types were defined including unprocessed aliments, major miscellaneous categories and food types determined by the main ingredient.

Some of the defined properties include nutrition elements such as fat, fiber, carbohydrate, etc.

Also for diabetes control, Hong and Kim [8] implemented web-based expert system for nutrition counseling and management based on ontologies. This system uses food, dish and menu database which are fundamental data to assess the nutrient analysis. Clients can search food composition and conditional food based on nutrient name and amount. The system is able to organize food according to Korean menus, and it is able to read nutrient composition of the each food, dish and menu.

The Food-Oriented Ontology-Driven System (FOODS) [7] is another ontology based expert system of a counseling system for food or menu planning. It uses a food-oriented ontology to implement a system which has two user interfaces, one for cookers and another for costumers or users that want advice on meals.

Suksom et al. [10] implemented a rule-based system for a personalized food recommender system, aimed to assist users in daily diet selections based on some nutrition guidelines ontology and focused on personalization of recommendation results by adding user's health status information that may affect his/her nutrition need.

Our work adopted some food ontology design schemes from [6-10]. However, comparing to [8-12], our work was focus only in weightlifting athletes. We extended the personalized food ontology defined in [8, 10] by adding information related to athletes' training program that may affect their nutrition need and unifying the food and sport ontologies. Our recommendations are based on sport nutrition guidelines, which were transformed into rule-based knowledge.

III. NUTRITION BACKGROUND

A. Periodized nutrition for the yearly training programme

In the course of a year, athlete training is divided in different cycles manipulating variables such as volume, frequency and intensity in order to meet season demands and schedule. As these variables change, the food of athletes should also change to meet different nutritional demands. Usually, a one year training cycle, a macro-cycle, is divided in micro-cycles, ranging from one day to a week, and meso-cycles, ranging from a week up to three months. Also, four phases can be identified in training: general preparation, specific preparation, competition, and transition. As the training plan comprises phases and cycles to manipulate training variables, so food needs should be in synch with this plan in order to maximize the athlete results in each phase (Fig. 1).

B. Energy Requirement

Meeting energy needs is a nutrition priority, in order to maximize athletic performance. To this goal, the energy provided to the athlete should equal the energy he needs, being this estimation a critical factor for nutrition. Besides the training plan, energy needs of an athlete depends on his prior nutritional status and sex, being factors such as heredity, age, body size, influential in such calculation.
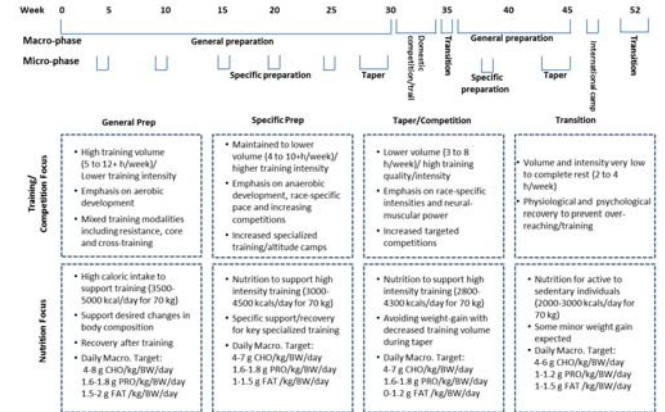

FIGURE 1. GENERAL NUTRITION RECOMMENDATIONS DURING DIFFERENT YEARLY TRAINING PHASES FOR STRENGTH AND POWER ATHLETES. NUTRITION RECOMMENDATIONS FOR A 70-KG STRENGTH AND POWER SPORT ATHLETE. (ADAPTED FROM [2, 11])

One of the most common ways to estimate the total energy expenditure (TEE) is using the called factorial method, by first estimate resting metabolic rate (RMR) using a prediction equation and then multiply RMR by an appropriate activity factor (both general and specific activity) (1). In general it is best to use the RMR prediction equation most representative of the population with whom you are working. For both active men and women, the Cunningham equation best predicted RMR; the Harris-Benedict equation was the next best predictor [12].

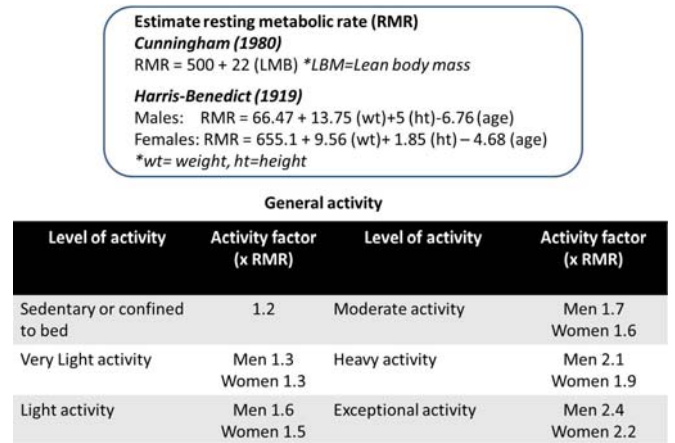$$TEE = (RMR \times General\ Activity) + (RMR_{(per\ hour)} \times METs) \quad (1)$$

FIGURE 2. THE CUNNINGHAM AND THE HARRIS-BENEDICT EQUATION FOR ESTIMATING ENERGY REQUIREMENT FOR ADULTS (ADAPTED FROM [12])

Specific activity: Weight Lifting METs	
Type of activity	METs
Weight lifting, power lifting, or body building, vigorous	6.0
Weight lifting, power lifting, or body building, light or moderate effort	3.0

FIGURE 3. THE METABOLIC EQUIVALENT FOR WEIGHTLIFTING. [13]

C. Daily Menu

A menu defines the food composition that is consumed by an athlete for his/her meal in one meal time or in one day. A balanced menu is a menu which consists of varied foods in appropriate quantities and proportions, to fulfill the nutritional needs of the athlete [13].

To calculate the total calories contained in every menu, we used the data from the dataset "Nutritive values Thai food" provided by Nutrition Division, Department of Health, Ministry of Publish Health (Thailand) and a software named INMUCAL provided by the Institute of Nutrition, at Mahidol University.

IV. ONTOLOGY

For this project we need a knowledge based framework and for that, it was developed a unified ontology merging nutrition and sports concepts.

Ontology in the computers science field is a data model that describes concepts (classes) in a specific domain and also describes their relationships. Ontology was successfully used to share concepts across applications and exchange information; ontology exchange information based on semantics rather than using syntax [14].

Compared to object-oriented programming where we center around methods on classes, and we make design decisions based on the operational proprieties of classes, in ontology we make the decisions based on the structural proprieties of a class.

There are four main elements of ontology, concepts or classes, individuals, properties and relationships that together make it a knowledge base. Classes are collections of objects, sets or abstract groups, describing concepts in the ontology specific domain; they can contain both a subclass that describes more specific concepts and an individual. An example of a class would be a Food class that would contain various subclasses like food type and food group. Individuals are the basic components of ontology. The individuals may be concrete concepts like a specific menu or an ingredient or an abstract one like numbers. Properties are related to individuals or class, as they are something that define or explain them. There are two types of properties: datatype used to assign a valor to a property or class, (e.g., a menu hasEnergie 150j) or object type meaning an object can be attributed to other (e.g., menu A hasIngredient b). The last of the main elements of ontology are the relationships that consist in all relations between classes and individuals. So, ontology is the exact description of things and the relationship among them.

V. EXPERT RECOMMENDER ENGINE

The recommender engine will interpret the ontology data in OWL (Web Ontology Language) format that is a standard ontology language designed for processing web information. OWL is written in XML and so, it can be exchanged between different computers and different applications.

The expert engine will perform questions on the ontology data to get back the nutrition/food data saved there, as well as inferring on athlete information and preferences to give the menu recommendations for each specific case. The application for insertion of the data will be developed in Java and will work with JESS API for the interaction with the ontology.

VI. IMPLEMENTATION

The unified Sports and Nutrition ontology was developed in Protégé [15], a free and open-source platform that allows users to build an ontology in OWL. Protégé also allows the use of SWRL rules [16] and query's and the use of PELLET [17], a reasoner used in this project.
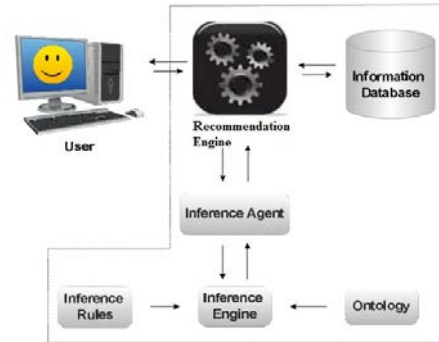

FIGURE 4. KNOWLEDGE BASE FRAMEWORK FOR FOOD AND NUTRITION RECOMMENDATION ENGINE IN SPORTS

A. Ontology Development

The development of the ontology involves specification and definition of the four main elements of ontology such as classes or concepts, the individuals, the proprieties and all the relationships. In this case we decided starting with only one specific sport the weightlifting by following a top-down approach. We started with the definition of the most general concepts in the domain and then, subsequently, the specialization of those concepts. Such ontology was modeled around four main concepts: Athlete, Food, Nutrition and Sports and it consists of 120 classes, 950 individuals and 25 properties.

The Athlete Concept: The athlete class represents the concept of the athlete profile with the athlete information saved in a database providing all the necessary information about the needed personal data like height, weight, age, etc...

The Food Concept: The food class is the root of this problem and represents the concept of the food which will have multiple subclasses: Food Group, Food Type, Process Type, and Type of Meals.

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- *Food Group* - this subclass will be divided in 5 groups of food like the Food Pyramid, all the 5 groups will have subclasses for even more specific type of food (e.g., in meat group there are different types of meat like beef or pork). This is the biggest concept where all the ingredients of all the menus will be.
- *Food Menu* – this subclass represents the different type of food items like main dish, dessert snacks or beverages. Inside these subclasses will be all available menus/items divided in those 3 categories.
- *Process Type* – represents how that food item was cooked (e.g., baked, roasted, and smoked).
- *Type of Meals* – this subclass represents the food item advised time of ingestion. (e.g., during dinner, lunch, breakfast or during training sessions). All food items can have more than one type.

The Nutrition Concept: The nutrition concept represents all the nutrition needs of an athlete and all the nutrients present in an ingredient/food item.

- *Nutrient Type* – all nutrients presented in all ingredients and food items are here listed.
- *Nutrition Level* – the level of nutrients per ingredient and food item and represented here, like low carbohydrates and high level of fat.
- *Nutrition Goal* – the amount of nutrients that meet the requirement.
- *Nutrition Plan* – special plan that athletes need, like maintain weight/ increase muscle or decrease weight/maintain muscle.

The Sports Concept: The sport concept represents athletes' characteristic which affect their nutrition need.

- *Anthropometric characteristic* – body type of athletes consist of endomorph, mesomorph, and ectomorph, which correspond to body fat percentage of athletes.
- *Periodization of training* – the systematic planning of athletes training consists of general preparation phase, specific preparation phase, competition phase, and transition phase. In each phase, the athletes' energy need is different.

After all the ontology was modeled and implemented, we validated the OWL using PELLET reasoner.

B. Rule Engine

The rules were developed using SWRL Protégé editor, and all tested from the SQWRL tab which runs a Protégé application that allows the query of the ontology inside Protégé. The rules were defined using nutrition and sports knowledge for the recommended energy and nutrients need for specific training types and specific ages, height etc. The more restrictions the user has less food menus will be recommended.

All those rules were written in SWRL (Semantic Web Rule Language), a language that allows us to make rules and query the ontology via java, so we can get the menus in our application with the specific rules constrains.

C. Expert Recommender Engine Application

The Java application was developed so a user can add all the needed data and then received the specific menus; all the data can be saved in a database for future using and gives the ability of updating that data. The application will work with the API Jess [18], a rule engine full compatible with OWL and SWRL.

The first menu of the user application [Fig. 6] will be the athlete profile menu where the athlete will add his information (age, name etc...). All data will be saved for future using in a database, and some variables of that menu can be retrieved from sensors. For requiring menu recommendations, various variables have to be added both in training part and preferred food. In the training part: Weight, Body Fat and Muscle Mass goal, Athlete level, Load, Repetitions of training and the date of the competition will be necessary for better estimation of the energy needs to achieve the goal.

The athletes can also choose the non-favorite and favorite menus and ingredients, so the system will avoid the non-favorite and will choose between the menus with the favorite ingredients. They can also choose for how many days they want the chosen recommendations and if they want the menus with supplements or not and want the special process type of cooking (e.g., steaming, baked etc.) [Fig. 7].

After the submition of the training and food preferences it will be possible to received various types of reports like via email or in the application itself [Fig. 8]. All the user requests together with the profile data will be transformed in a SQWRL query that will question the ontology, producing all the recommendations results following the rules previously saved into the ontology.
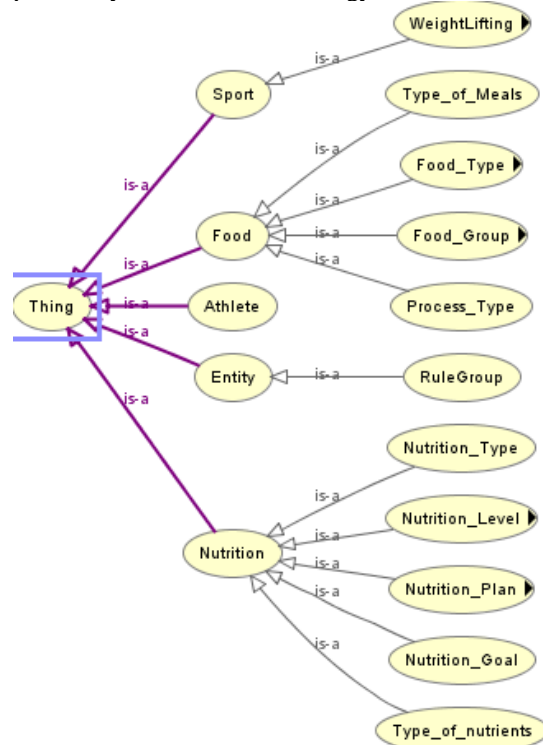

FIGURE 5. OVERVIEW OF THE FOOD, NUTRITION AND SPORTS ONTOLOGY

FIGURE 6. THE USER APPLICATION FOR INSERTION OF ALL THE PERSONAL ATHLETE DATA

FIGURE 7. THE USER APPLICATION FOR INSERTION OF TRAINING GOALS AND FOOD PREFERENCES

FIGURE 8. EXAMPLE OF RECOMMENDED RESULTS OF MENUS FOR 1 DAY

VII. CONCLUSION AND FUTURE WORK

This paper describes the development of a personalized food and nutrition ontology working with a rule-based knowledge framework to provide specific menus for the weightlifter's diary nutritional needs and personal preferences.

On-going work is the real-time data gathering through sensors and automatically updating of database without user intervention. This will give the possibility of, after every sensor measuring, the recommendations can be updated for the better athlete needs, and it will also allow the use of the alerts every time some parameter is not correct or the athlete is failing with his training and is goal.

For being able to communicate with the sensor via Java application we will need to create a DLL (Dynamic Linked Library) in C++, because Java doesn't allow us to directly communicate with hardware. For the communication between the DLL and Java we will use JNI (Java Native Interface), a framework that specifies a communication protocol between Java code and external library's, so enabling java interface with the C++.

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TABLE I.   SOME EXAMPLES OF POSSIBLE SCENARIOS AND QUERIES

Scenarios for energy needs	Queries
User A is male, prefers meats, has 63kg, 162 cm., He is 25 years old, body fat is 13%, muscle mass is 54.8 kg, his objective is 62kg, the training phase is general preparation: hypotrophy and he wants main dish lunch menu.	If(gender = male , athletefav = meat and heighobj = (62-61) and age = 25 and bfat = 13 and mmass = 54.8 and train = HTrophy and menu = mdish and time = lunch) Then recommendedmenu = (hasEnergy(600 <= energy <= 660) and hasMeat)
User B is female, wants low fat , has 97kg 165 cm., She is 26 years old, body fat is 25%, muscle mass is 72.7 kg, her objective is 94kg, the training phase is specific preparation: strength and she wants main dish dinner menu.	If(gender = female ,athletefav = pork and heighobj = (94-97) and train = Specific and age = 26 and bfat = 25 and mmass = 72.5 and menu = mdish and time = dinner) Then recommendedmenu = (hasEnergy(843 <= energy <= 903) and low_fat)