OHEN: An Ontology for Health through Exercise and Nutrition

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1 Introduction

There is no shortage of data collected that pertains to the health of individuals, however, the public is often not able to put this abundance of information to use in a meaningful way. Studies with health findings that contradict one another are becoming commonplace (Rosenbloom, 2019). People are confused in terms of how to put any of this data to use as indicated by soaring rates of obesity in the United States in particular, (Hales, 2020) (Henry, 2018). To this end, we have created OHEN, an Ontology for Health through Exercise and Nutrition. OHEN is a preliminary ontology that seeks to connect various phases of one's health. In particular, OHEN focuses on linking food/nutrient intake with physical exercise in order to provide more sophisticated recommendations for a user to improve their own health through various means. Because of the seemingly limitless potential outcomes that various combinations of food and exercise can have on one's health, OHEN should be viewed as an exploration into defining a few well established principles from which we may continue to expand upon.

2 Building OHEN

In building this ontology, we have identified two pre-existing ontologies that will be of particular value. The first ontology is the Ontology of Physical Exercises (OPE) which "provides a reference for describing an exercise in terms of functional movements, engaged musculoskeletal system parts, related equipment or monitoring devices, intended health outcomes, as well as target ailments for which the exercise might be employed as a treatment or preventative measure" ("Ontology of Physical Exercises: NCBO BioPortal"). Our second ontology is the FoodOn Food Ontology (FoodOn), which was "built to represent entities which bear a 'food role' and is initially focused on categorizing and processing of food for humans" ("The FoodOn Food Ontology: NCBO BioPortal"). We merged these two ontologies to create the basis of OHEN from which we were able to establish relationships between foods from FoodOn and exercises/health outcomes from OPE.

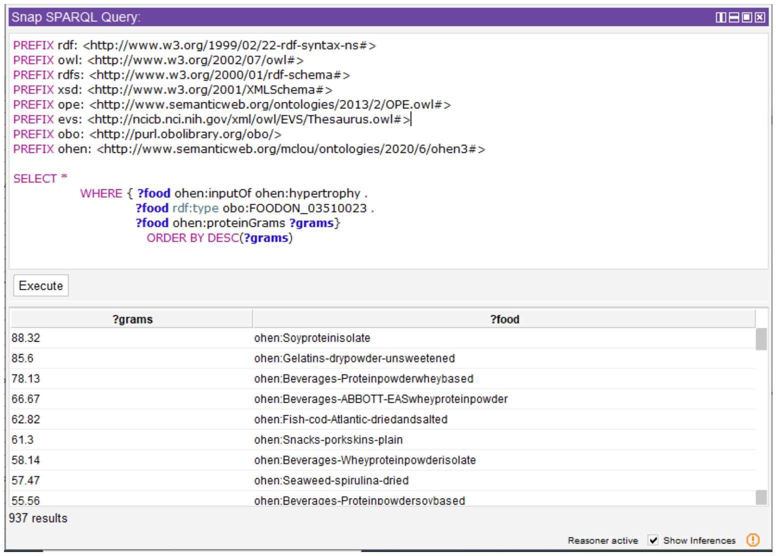

Figure 1: A query displaying foods that OHEN considers helpful for hypertrophy

OHEN was primarily designed in the application Protege. Protege is a free and open source ontology editor developed at Stanford and one of the leading ontological engineering tools (Gasevic, Dragan, & Devedzic, 2009). Its features include a wide range of file formats to support more interoperability than most other free ontology editors, a built-in inference engine, a wide range of visualization options, and the ability to perform SPARQL queries in the application itself. This last point is particularly important. OHEN is designed to provide the most value when providing query results. For example, a very simple query as depicted in Figure 1 might display several foods that OHEN considers to be helpful in hypertrophy.

The FoodOn ontology defines many classes of foods, most relevant for OHEN is the "foodon:nutrition-related claim or use" class. This class defines many subclasses that categorize food based on the food's various nutritional aspects, such as protein, cholesterol, or magnesium values. This provided the fundamental structure for OHEN, however, in order for OHEN to be of any use we needed to create instances of these classes. To accomplish this, we used the USDA FoodData Central Data ("FoodData Central Download Data"). This data contains the nutritional content of 65 different nutrients from a wide variety of 2,730 foods. We then considered some of the most potentially relevant nutrition related claims that could be made about a food such as "low in sugar" or "high in fiber", and filled relevant classes in OHEN with the appropriate foods. More detail about how this was accomplished and further considerations that went into classifying various foods can be found in the accompanying Jupyter Notebook entitled “Building OHEN”. Certain data properties were also added to various food instances to further enrich the data. These processes and considerations are also further detailed in the Notebook.

3 Use Cases

3.1 High Protein & Hypertrophy

From here, we created a few relatively well established relationships between foods and exercise/health. For example, the object property “ohen:inputOf” has a domain of “foodon:nutrition-related claim or use” and a range of “ope:Health-Outcome”. One fundamental relationship that our ontology should model is that if a food is high in protein, then it will be a contributing factor to muscle hypertrophy (Stark, Lukaszuk, Prawitz, & Salacinski, 2012). To do this, we create an instance of the “ope:StrengthFitnessHealthOutcome” class called “ohen:hypertrophy”. We assert that the class “foodon:high protein food” is a subclass of “inputOf value hypertrophy”. This value statement allows the reasoner to infer that every instance of the “foodon:high protein food” class will be an input of “ohen:hypertrophy”.

Figure 2: A screenshot showing how “inputOf hypertrophy” is inferred

From here we can see the true power of OHEN. For example, we have 937 unique foods from the USDA database that can technically be classified as “high in protein”, (meaning that they have at least 20% of their total energy coming from protein). It would be unreasonable to assert each one of these directly as an “inputOf” hypertrophy, yet by creating this relationship between any high protein food and hypertrophy we are able to provide many more detailed results. Note that while Protege allows for SPARQL queries, the freely available “Snap SPARQL Query” plugin is required to return query results from inferences (Horridge & Musen, 2016).

3.2 Exercise & Hypertrophy

Of course there are more inputs necessary for hypertrophy than simply eating protein, most important of which is an actual stimulus to the muscle (Beardsley, 2018). To illustrate this, we created instances of various exercises, such as a bicep curl for example. We create "ohen:bicepCurl" to have "rdf:type evl:Isotonic Exercise", ("evs" is a prefix used in OPE). Now, note that an isotonic exercise is one in which a muscle is contracted over a range of motion with a constant weight. It is therefore reasonable to make the assertion in OHEN that any one of these exercises "ope:HasIntendedHealthOutcome value hypertrophy". Similar to our high protein foods example, our reasoner can now infer that every isotonic exercise is intended to increase muscle size.

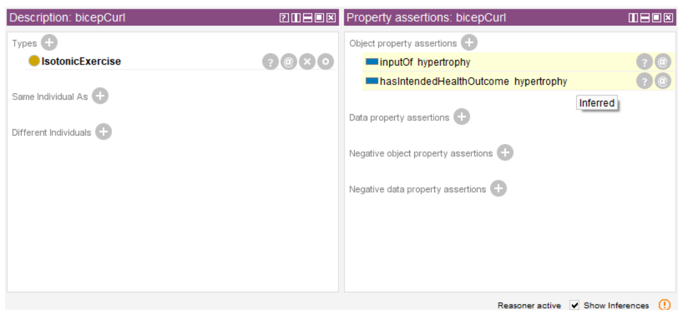

Figure 3: A screenshot showing inferences of bicepCurl after asserting it is an IsotonicExercise

3.3 Avoiding Injurious Exercises

Now, let's say that the user has an injury in his triceps and wants to avoid any exercises that may aggravate this muscle group. OPE defines several ways in which a member of class "ope:Exercise" may "ope:engage(s)" some "evs:MusculoskeletalPart". To engage a muscle, OPE defines "contracts", "extends", "flexes", "rotates", and "stretches". For simplicity, we are most interested in the first two of these.

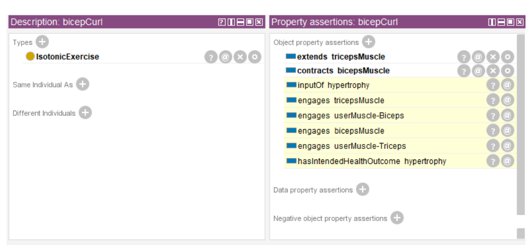

Figure 4: Our two assertions about the bicepCurl result in several inferences

When creating the bicepCurl exercise, we assert that not only does it contract the biceps muscle group, but it also extends the triceps group. “Contracts” and “extends” are both sub properties of “engages”, and so a bicep curl exercise engages both the biceps and triceps. To avoid exercises that may aggravate the triceps, one option we perform would be a query similar to that shown in Figure 5.

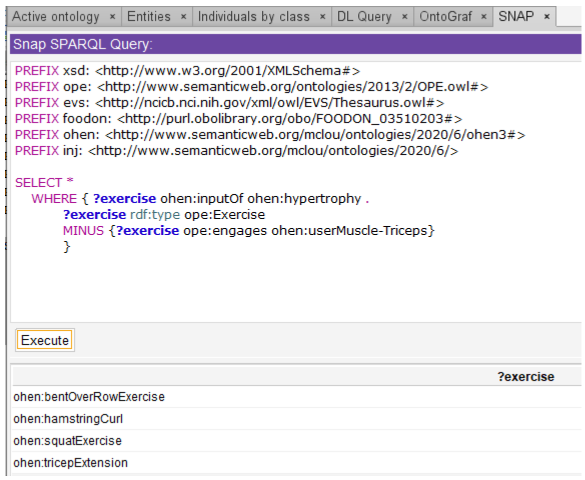

Figure 5: A SPARQL query for exercises that do not engage the triceps

While there is nothing necessarily wrong with this query, it feels a bit cumbersome to explicitly name the muscle groups we might want to exclude. Our “Building OHEN” notebook details how we have created user instances of each muscle with data property values of true/false booleans for the object property “ohen:isInjured”. We can use the inference capabilities of Protege to build a more sophisticated query in OHEN that will exclude all exercises that engage any muscle groups that are injured for a user. When creating this user’s muscle groups, we claim that this user has an injury in his triceps. The query demonstrated in Figure 6 demonstrates how we can utilize SPARQL to avoid any exercises in which an injured muscle might be engaged. The query first finds everything that is an inputOf hypertrophy, and then limits this to only exercises, (note that this may seem redundant at first, but we must remember that there are other types of exercise such as jogging which would not be considered an inputOf hypertrophy). The third line gathers the muscle groups that are engaged by the exercises OHEN contains, and the final line limits results to those that have the data property “isInjured” as “false”. Note that this query also displays the exact muscles that are targeted by each exercise.

The key difference between the previous two queries was that in the first one, we specifically designated a user’s muscle group to exclude. The second query was able to use another feature that we added to OHEN to be able to infer that a user’s triceps might be engaged by a particular exercise, without asserting this

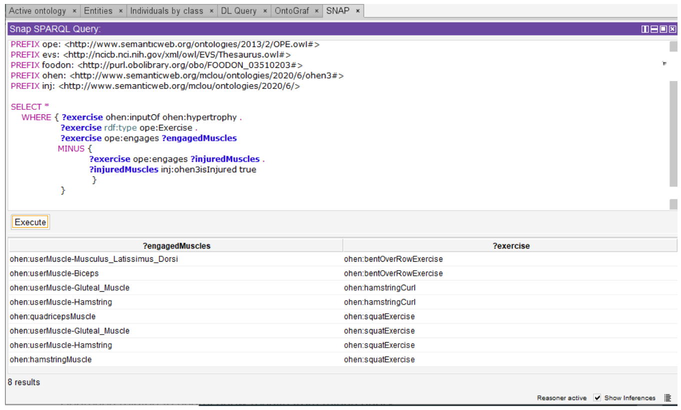

Figure 6: A more sophisticated SPARQL query for exercises that do not engage the triceps

fact for every new user that might be added. Instead, Figure 7 demonstrates how we are able to infer that all instances of the evs:Triceps class are engaged by various upper body exercises. We have included the following exercises in OHEN: benchPress, bentOverRow, bicepCurl, hamstringCurl, squatExercise, and tricepExtension. For each of the major muscle groups that these exercises engage, we have asserted similar statements as to those shown in Figure 7. In a very similar manner as to how we were able to infer that all high protein foods could be an inputOf hypertrophy without asserting each individual food item, these few statements allow OHEN to become much more effective in displaying customized results based on a user's particular needs.

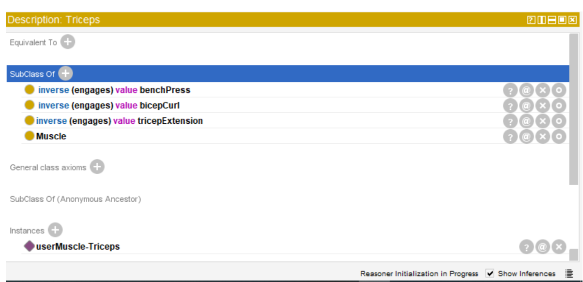

Figure 7: OHEN can infer that all members of the Triceps class will be engaged by various exercises

3.4 Nutrition to Heal an Injury

Now, there is obviously more to health than simply hypertrophy. Suppose our user wanted to learn how he could actually use nutrition to improve his triceps injury. Sleep helps the body repair itself faster (Vyazovskiy, 2015), and so we have introduced an instance of “evs:VeryLightExercise” as “ohen:sleep”.

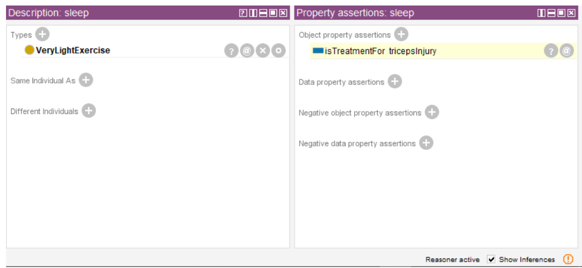

Figure 8: Sleep can be used to improve a triceps injury

OPE also already comes with a class “evs:Injury” and an object property “ope:isTreatedBy”. By asserting “Injury isTreatedBy value sleep” we are able to infer that all injuries could potentially be improved by enhanced sleep.

Now, knowing that magnesium is useful for enhancing sleep, (Cao, et al., 2018), we defined a new subclass “highMagnesium” under “ope:high name of vitamin/s and/or name of mineral/s nutrition claim” and asserted that “highMagnesium” is a subclass of “ohen:inputOf ohen:sleep” to express the concept that sleep can be improved by increased magnesium consumption. Perhaps our user also happens to know that zinc is useful for injury recovery as well (Lin, et al., 2017). The user could then order the query results by the milligram content of foods as shown in Figure 9.

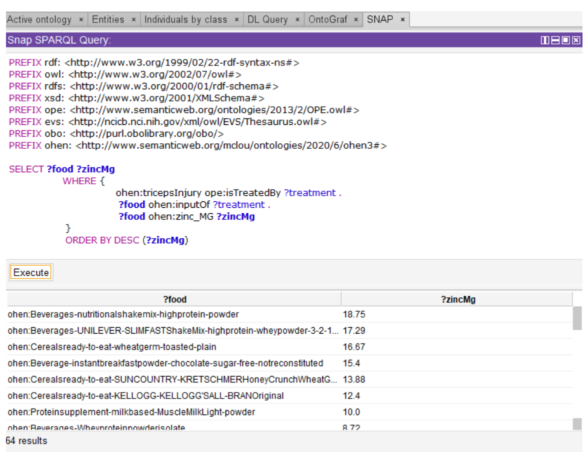

Figure 9: Foods that might help heal a triceps injury (high magnesium), ordered by their Zinc content

3.5 Closing Thoughts & Future Considerations

This last example shows the near endless combinations of potential health protocols that could be established for a user. Perhaps this user was following a ketogenic style diet and wanted to only look for foods that were a part of the "low sugar foods" class. Or perhaps the user felt a cold coming on and wanted to find foods that could potentially help with such an illness. It would be simple to implement these desires for a user by modifying the query results demonstrated throughout this exploration and defining similar relationships between something like an illness and a high vitamin C food as enhancing sleep and high magnesium foods.

Because of how complex the human body is, it might be impossible to ever completely define ways in which the nutritional components of various foods may interact with the body when consumed. Patterns that scientists long believed to be "healthy" are constantly being challenged by emerging new science, and OHEN would need to be updated accordingly. There is also much room for OHEN to grow not only by establishing more relationships between nutrients/food and health outcomes, but also expanding the data that OHEN does include such as adding more exercises, muscle groups, and classes of various foods. OHEN was created not as the definitive guide to becoming the optimal human but to establish a model for a user to start to understand what impacts certain foods may have on the body.

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