FitMe: Ontological approach to Personalized Exercise Recommendations

Anirban Acharya, Abhirup Dasgupta, Dominick Iadevaia, Johnny Sun

[1]Rensselaer Polytechnic Institute
110 8th St
Troy, New York 12180
achara@rpi.edu, dasgua3@rpi.edu, iadevd@rpi.edu, sunj13@rpi.edu

Abstract

Exercise is crucial for overall health, improving cardiovascular fitness, muscle strength, and mental clarity. Many struggle to find safe and effective workouts that fit their busy lives and personal goals. A personalized exercise plan that includes flexibility, convenience, and enjoyment, while considering any injuries or illnesses, can improve adherence to fitness goals and promote long-term health benefits. Our work introduces an ontological approach to help people select appropriate exercises based on their goals while factoring in any illnesses or injuries they may have. The underlying ontology was developed based on information and concepts from various reputable sources, such as Physical Activity Ontology (Kim, Mentzer, and Taira 2019), the Ontology-Based Physical Exercise Recommender System for Underweight Using Ontology and Semantic Web Rule Language (Juliant, Baizal, and Dharayani 2023), Designing an ontology for physical exercise action (Dash et al. 2018) cross-referenced with popular websites and books focusing on health and physical exercise such as Encyclopedia of muscle & strength (Stoppani 2005), muscleandfitness.com to ensure a comprehensive and reliable framework. The gap between concepts and expected output was bridged by developing semantics using description logic in Protege. The framework was then tested on a developed use case that focuses on individuals seeking customized training plans that accommodate their specific health conditions and fitness objectives which were represented by different competency questions. Although we do not have any quality metrics, the framework was evaluated for its ability to match the recommended exercises with the user goals, comparing them with a predefined set of exercises expected from the ontology for the set of competency questions that was developed. This evaluation demonstrated the effectiveness of using an ontology-based approach to personalize fitness recommendations for users with varying needs.

Introduction

An increasing fascination with the promotion of a healthy lifestyle prompts inquiries on the most effective workout regimens that accommodate a diverse range of fitness levels and individual preferences, thus requiring further exploration into how tailored training protocols can enhance user engagement and adherence. In this regard, the fundamental principle of 'one size fits all' is inapplicable to fitness programs, as intrinsic variability in personal objectives, physical abilities, and motivational factors requires customized strategies that correspond to the unique situations of each individual. The primary objective of our application is to help people identify exercises and a foundational one-week regimen that is compatible with their specific levels, preferences, and any pre-existing injuries. The demographic of users encompasses a wide spectrum, ranging from professionals to novices within the health and wellness domain. Although our application is not intended to replace the expertise of a professional, it serves as a valuable resource to complement their guidance by providing users with easily accessible and personalized workout options that can enhance their fitness journey. The health objectives currently supported by our application include the improvement of cardiovascular fitness, injury rehabilitation, reduction of body fat, muscle hypertrophy, mass enhancement, improved flexibility, strength development, explosiveness enhancement and functional training.

Technical Approach

The Use Case

The proposed use case focuses on helping people achieve their fitness goals through the provision of customized workout recommendations specifically designed to accommodate their unique physical requirements and restrictions. The application presupposes that users will articulate their body objectives, which can include weight loss, muscle gain, or enhancement of overall health, in conjunction with any injuries or disabilities that could potentially influence their range of motion or increase their risk of injury. The system employs an ontology to propose efficient workout regimens based on these inputs, thus ensuring both safety and efficacy. Workouts are systematically categorized into structured cycles that encompass push, pull, and cardiovascular routines, offering a comprehensive approach. Although the primary demographic includes individuals who frequent gyms at various levels of experience, stakeholders encompass a broad spectrum from fitness aficionados to professional trainers. The use case aims to mitigate prevalent challenges faced by novices, such as uncertainty in direction or ineffective exercise regimens, making fitness more accessible and oriented toward specific goals for all individuals.

Structuring

The ontology was organized to represent key components of exercise science: exercise type, goals, targeted muscles, injury considerations, and intensity levels. The terms were gathered from trusted sources, such as academic journals and fitness literature, ensuring a solid foundation. The definitions were sourced from reliable dictionaries and expert publications for clarity. Additional terms, labels, context, and usage examples were collected to enhance the ontology, serving as the foundation for a knowledge graph that provides recommendations. Refer to Figure 1 for the process followed to develop the ontology for the proposed use case.

Semantics

For the use case, a comprehensive set of competency questions was formulated to ascertain that the workout regimens are congruent with user objectives and inclinations, thereby addressing critical dimensions such as exercise selection, progression monitoring, and recovery methodologies. To address the competency questions, the integration of semantics within the ontology facilitated multiple inferences to respond to various questions pertaining to user requirements and preferences, thereby ultimately augmenting the customization of fitness programs. For instance, one of the competency inquiries pertained to the formulation of a workout regimen aimed at fat loss and muscle hypertrophy for a user with a knee ligament injury. This necessitated the establishment of clearly defined classes by utilizing description logics to derive inferences regarding the selection of low-impact exercises that would foster fat loss while concurrently permitting muscle development without aggravating the existing injury.

The Conceptual Model

Developing a conceptual model is essential for developing knowledge-intensive systems. One of the biggest benefits is that it provides a clear picture for the extraction of relationships. However, the method of developing a concept model can be a **top-down**, **bottom-up** or a combination of both (Noy and McGuinness 2001). For our application, a combination of both the bottom-up and top-down approach was taken to build the concept model sufficient to capture relevant concepts to answer all competency questions.

The conceptual model offers a coherent structure for the organization and strategizing of fitness-related information, encompassing objectives, physical exercises, injuries, and individualized recommendations. It delineates a variety of fitness goals, such as cardiovascular endurance, weight reduction, muscle hypertrophy, recovery, and functional conditioning, thus allowing the system to accommodate a wide spectrum of user requirements. Exercises are systematically classified into strength, aerobic, isometric, and functional modalities, each category connected to pertinent anatomical regions, including the upper and lower body musculature,

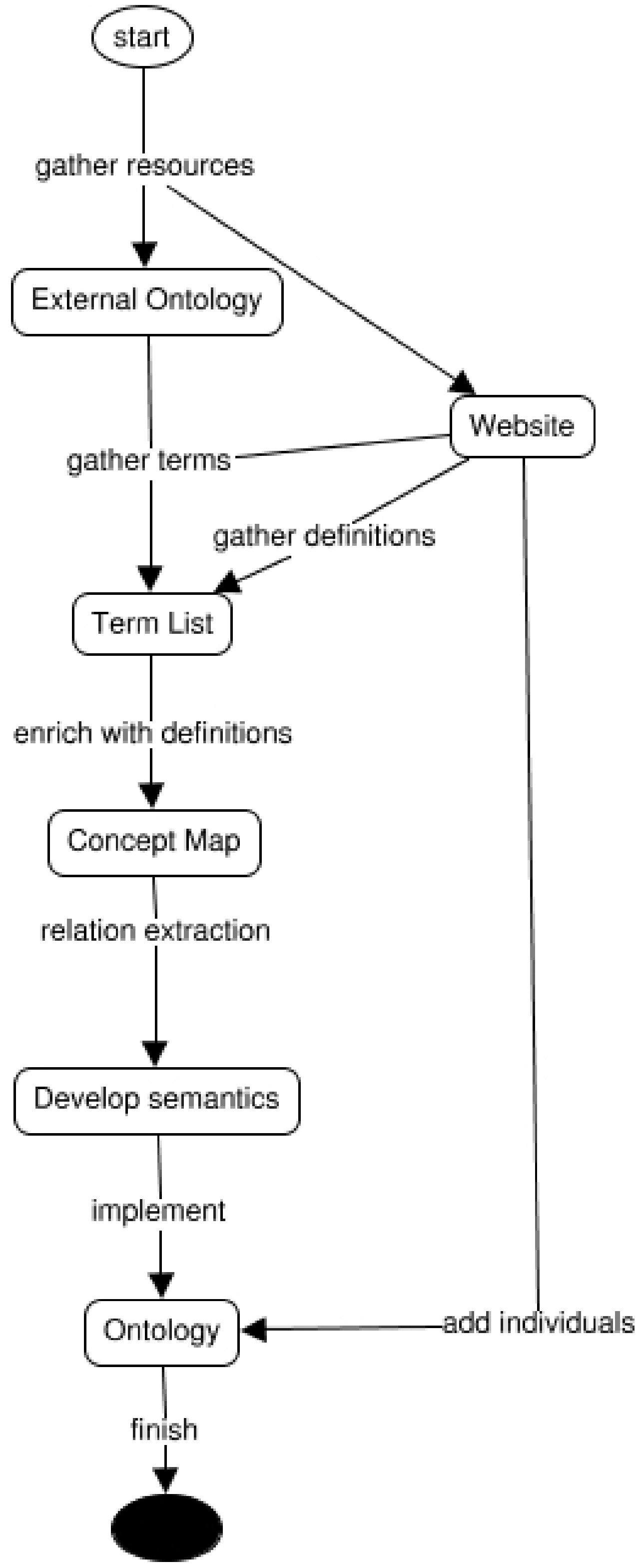

Figure 1: Flow diagram to develop our ontology

core, arms, and legs. In addition, the model integrates classifications of injuries, encompassing muscle, ligament, and osseous injuries, to guide exercise recommendations that are customized to individual limitations and safety considerations. The system advocates for a well-rounded exercise regimen, exemplified by "Push, Pull, Cardio" cycles, and incorporates recovery protocols for particular conditions, such as knee ligament injuries. By linking fitness objectives with executable training regimens while considering user-specific constraints, the conceptual map provides a comprehensive methodology to develop effective and customized fitness solutions. See Figure 3, which is a metamodel of our conceptual model.

The fundamental elements of our theoretical framework are elaborated on within the meta-model, which delineates the interrelations among the various aspects of fitness training and rehabilitation. This metamodel delineates the vertical categories (Goal, Planner, Exercise, Injury, User, Muscle Group, and Strain) for an in-depth exploration of the various factors pertinent to the formulation of individualized fitness regimens. Individuals invariably possess a specific objective, such as improving muscular strength, increasing cardiovascular endurance, or improving flexibility. Regardless of the predetermined objective, an exercise regimen will invariably adhere to a structured plan that is segmented into multiple days of organized exercises, facilitating progression and adaptation over time. Each training session is meticulously crafted to engage particular muscle groups while taking into account the individual's current fitness status and any preexisting injuries or limitations they may possess. Every exercise is associated with distinct muscle groups that play a role in the execution of the movements. Should an individual experience an injury that affects specific muscles, exercises that engage those muscles will be consciously omitted. Such deductions can be readily drawn utilizing the semantics established within the conceptual model that interconnects each of the vertical categories.

Knowledge Creation

In the process of building the foundational knowledge for the ontology, all concepts were meticulously delineated and the interrelations among them elaborated to guarantee unequivocal understanding of how each concept interacts with other pertinent concepts within the overall framework. In accordance with these relationships, the object properties were articulated with specified domains and ranges. For example, the phenomenon of injury has an impact on a collective of muscles. This relationship is represented by the property `affects(Injury, MuscleGroup)`, wherein `Injury` constitutes the domain, and `MuscleGroup` represents the range. Refer to Figure 2 for a compilation of object properties that interconnect various concepts. A systematic methodology was used for the organization of knowledge related to exercises, objectives, injuries, muscle groups, planners, strain levels, and user interactions. At the nucleus of this structure is the Exercise class, which is hierarchically subdivided into several subtypes, including `AerobicExercise` (e.g., Cycling, Running, Swimming), `FlexibilityExercise` (e.g., `DynamicStretching`, `StaticStretching`), and `StrengthExercise` (e.g., `ResistanceExercise`, `IsometricExercise`). In addition, the subcategories encompass specialized exercise assemblies, such as `SetOfBackExercises` and `SetOfBicepExercises`, which are further classified by intensity levels (e.g. Light, Moderate, Strenuous). The Goal class encapsulates user goals, encompassing a spectrum of physical fitness outcomes including `FatLoss`, `MuscleGain`, and `StrengthGain`, as well as functional aspirations such as `Recovery` and `FunctionalTraining`. The `Injury` class is categorized into subtypes, comprising `BoneInjury`, `LigamentInjury`, and `MuscleInjury`, which are further specified by particular body regions (e.g., `ArmMuscleInjury`, `LegMuscleInjury`). Complementing this structure is the `MuscleGroup` class, which is segmented into `UpperBodyMuscleGroup` and `LowerBodyMuscleGroup`, with additional subdivisions such as `LegMuscleGroup` and `GlutealMuscleGroup`. The `Planner` class facilitates the development of structured workout regimens, featuring pre-established plans such as `BackDay`, `LegDay`, and `CardioDay`, as well as specialized plans like `KneeLigamentInjuryAgnosticStrengthGainPlan` and `RecoveryDay`, customized to meet individual user requirements. The `Strain` class categorizes exercises according to intensity levels—{`Light`, `Moderate`, `Strenuous`}—thereby guiding safe and effective training protocols. Ultimately, the `User` class signifies the individual engaging with the ontology, serving as a central point for tailored recommendations.

Related Work

A multitude of ontologies pertinent to health, fitness, and exercise have been established to standardize, categorize, and facilitate semantic reasoning regarding concepts in the domains of physical activity and exercise:

1. Physical Activity Ontology (PACO) (Kim, Mentzer, and Taira 2019): This ontology was created to help organize and standardize various descriptions of physical activity. It offers an intricate hierarchy and vocabulary for a variety of types of physical activity.
2. Ontology of Physical Exercises (OPE) (Wang and Dou 2015): This ontology is intended to represent data related to exercise games, including types of gaming equipment, engaged musculoskeletal systems, and associated health outcomes. It facilitates a consistent representation and analysis of data related to exercise gaming.
3. Linked Fitness Training (LiFT) Ontology: This ontology offers a semantic model designed to facilitate the development of personalized exercise and fitness regimens by combining exercises with fitness objectives, user preferences, and physical attributes.
4. Ontology-Based Physical Exercise Recommender System (Juliant, Baizal, and Dharayani 2023): Designed for individuals classified as underweight, this ontology integrates user profiles, governing rules, and concepts to

recommend appropriate physical exercises depending on individual factors.

5. Ontology-supported Exploratory Search for Physical Training Exercises (Kotzyba et al. 2014): An exploratory search engine that simultaneously accesses internet resources and a local knowledge base given in the form of ontologies that can be extended during exploration with new information, thus making the search process adaptive and iterative.
6. Designing an Ontology for Physical Exercise Actions (Dash et al. 2017): The proposed ontology lays down a hierarchical structure following the human body structure along with various type of movement restrictions that facilitates flexible yet adequate representations.
7. Extensible Context Ontology for Persuasive Physical-Activity Applications (ECOPPA)(Hoda et al. 1970): This paper proposes the Extensible Context Ontology for Persuasive Physical-Activity Applications (ECOPPA), a formal context modeling scheme for applications that promote physical activity.

These ontologies encompass diverse aspects of physical activity, encompassing classification methodologies, equipment utilization, health outcomes, and tailored recommendations. They serve an essential function in facilitating the semantic structuring of exercise-related data, promoting interoperability, and bolstering individualized fitness interventions. While existing ontologies present valuable frameworks for the study of physical activity and exercise, our ontology differentiates itself in several notable aspects: Emphasis on Injury-Aware Recommendations: In contrast to the majority of related scholarly works, our ontology integrates comprehensive considerations regarding injuries, explicitly correlating exercises with contraindications or necessary modifications. For example, it is capable of identifying exercises that pose risks for individuals with specific injuries (e.g., knee injuries) and suggesting safer alternatives. This characteristic promotes safe and efficacious exercise planning, a factor frequently neglected in other ontologies. Focus on Exercise Objectives: While ontologies such as PACO and OPA primarily concentrate on the classification of activities or sedentary behaviors, our ontology equally prioritizes exercise objectives, including fat reduction, muscle hypertrophy, flexibility enhancement, or endurance improvement. These objectives are directly associated with pertinent exercises, thereby establishing a more outcome-focused framework. Detailed Targeting of Muscle Groups: Our ontology furnishes a comprehensive taxonomy of muscle groups (e.g., biceps, hamstrings, gluteus maximus) and aligns them with specific exercises. This degree of detail permits precise exercise recommendations tailored to individual fitness aspirations, surpassing the generalized methodologies prevalent in numerous existing ontologies. Incorporation of Intensity and Modifications: Although related ontologies such as LiFT and OPE associate exercises with user profiles and equipment, our ontology distinctly integrates intensity levels (low, moderate, high) and exercise modifications. These characteristics facilitate the personalization of exercise regimens based on individual fitness levels and constraints, thereby

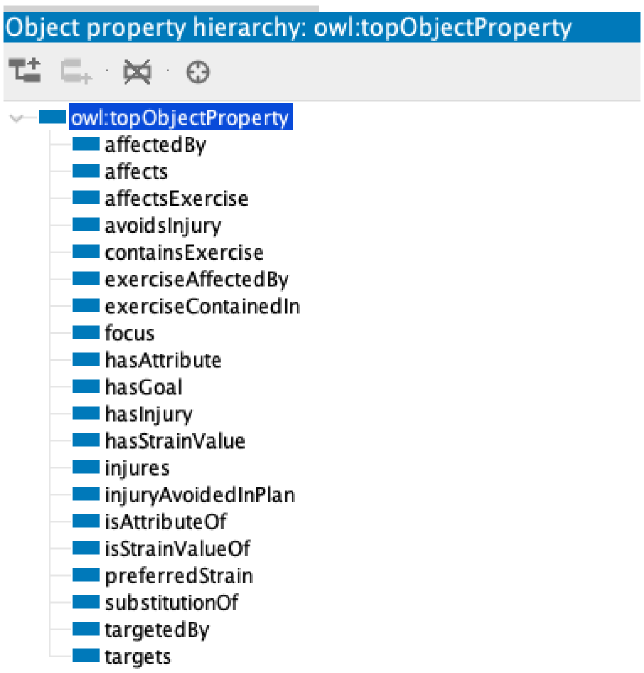

Figure 2: Object properties for the ontology

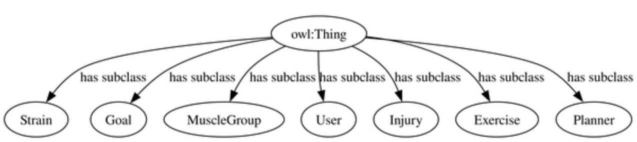

Figure 3: Meta-model of the ontology

enhancing the adaptability of recommendations. Contextualized Objectives and Limitations: Our ontology effectively bridges the divide between goals and constraints by associating exercises not only with desired outcomes but also with individual-specific variables, such as current physical limitations, age, and gender. This synthesis guarantees that recommended exercises are both outcome-oriented and attainable for the user. Competency Questions and Practical Use Cases: Unlike broader ontologies such as SMASH or PACO, which are constructed for general semantic integration of physical activity data, our ontology is specifically designed to address pragmatic competency inquiries, such as: ”Which exercises can assist a user in developing upper body strength without exacerbating knee strain?” ”What flexibility exercises are suitable for an individual in recovery from a shoulder injury?” Exclusion of Social and Behavioral Dimensions: Related works such as SMASH encompass social and behavioral facets, including social networking and activity sharing. Our ontology is exclusively focused on the physical dimensions of exercises and their resultant outcomes, thereby creating a streamlined model that prioritizes precision in exercise recommendations. Modular and Expandable Structure: Our ontology is conceived as a modular framework that can seamlessly integrate with wearable devices, fitness applications, or machine learning algorithms for dynamic exercise recommendations. While ontologies such as LiFT strive to facilitate personalization, our design explicitly accommodates adaptability for evolving technologies and user-specific inputs. By addressing deficiencies in injury-aware recommendations, goal alignment, and individualized constraints, our ontology offers a comprehensive and practical solution for exercise planning that enhances user safety, effectiveness, and adherence to fitness regimens.

Evaluation

Competency Questions

The evaluation of our ontology is based on how well it could satisfy our primary competency questions that we created when modeling. These questions were made in order to scope what the ontology should be able to answer. Our system was able to answer all these questions quickly and had the same answers that we expected it to output. The competency questions ranged from different complexities and allowed for direct checking with the cookie cutter answers that could prove the logic and semantics were working properly. The competency questions had a scope of a user that gives their body goals and any current injuries or diseases that may affect certain areas of the body. The scope of these questions could have been larger and more complex in order to ensure the system could answer incredibly complex questions, however knowing that it could solve basic ones should make it able to scale up easily.

The competency questions below are chosen so that we could evaluate different potential needs from users to personalize an exercise plan that allows them to achieve their goals without putting their body at risk. As labeled below, competency question 1 is a more involved question, giving two body goals as well as one injury. Questions 3 asked exercises given one body goal, a specific area of the body, as well as one injury. Questions 2 and 4 are more basic, testing out different goals to ensure our description logic was enough for the system to find answers. Question 5 was to check if we could give exercises for a specific body part as well as their goal.

Below are our competency questions:

1. Question: What is a good workout routine I can follow if I want to lose fat and gain muscle given that I have a knee ligament injury?
   Sample Answer: Bench Press
   Use of Semantics: Interprets knee ligament injury as needing light exercises for areas around your knee. Also interprets lose fat and gain muscle goals as any strain exercise, so it limits only leg exercises to a light strain.
2. Question: What are good workouts to build strength?
   Sample Answer: Seated Leg Extensions
   Use of Semantics: Interprets building strength as needing exercises that is on the moderate or strenuous strain.
3. Question: I’m looking into enforcing my back. Can you provide me with a back workout given I have a back injury?
   Sample Answer: Deadlifts
   Use of Semantics: Interprets enforcing as needing exercises that is of light strain. It then interprets that user is focusing on back and will only show back workouts. It also sees that the user has a back injury, interpreting as needling light exercises for back.
4. Question: I’m looking to start gaining muscle. Provide me with a workout cycle.
   Sample Answer: Lat Pulldown
   Use of Semantics: Interprets gaining muscle as needing exercises that is resistance training.
5. Question: I’m looking to develop strong legs. Can you provide me with a leg workout?
   Sample Answer: Barbell Back Squats
   Use of Semantics: Interprets developing strong muscles as needing moderate to strenuous exercises. Interprets legs as the focus area and will only show back workouts.

Discussion

Value of Semantics

In our ontology, we attempted to bridge the gaps between the domains of exercise, injuries, and muscle groups using clear, unambiguous, and well-defined relationships. This approach enables the system to accurately model the connections between exercises and the specific muscle groups they target, as well as the impact of injuries on these muscle groups. By ensuring that these relationships are semantically rich, the ontology facilitates meaningful reasoning that supports personalized workout recommendations, while also minimizing the risk of injury. This clear semantic structure is essential for making informed, data-driven decisions that are aligned with the user’s individual health and fitness goals. The main driver behind the semantic structure of our implementation is the use of description logic (DL) assertions on classes, which allow for the inferencing discussed below.

The general structure of our ontology enabled the generation of meaningful and insightful inferences. For instance, object properties such as `targetedBy`, `targets`, `isStrainValueOf`, and `preferredStrain` were utilized to describe relationships between muscles and exercises. Some examples of these relationships include which muscles were targeted by specific exercises, the strain value associated with those exercises, and the preferred strain values aligned with certain fitness goals.

An example of this structure is the `EnforceBackPlan`. This plan is assigned a strain value of `Light` and is designed to `target` the `BackMuscleGroup`. Through the DL's, the system infers that exercises such as `CableRows` and `FacePulls` are part of the `EnforceBackPlan`. Similarly, the `StrengthGainPlan` has description logic along with constraints on the domain and range to define the appropriate classes. At a high level, the system infers distinct workout days—such as `BackDay`, `ChestDay`, and `LegDay`. Each of these days contain a variety of exercises, which can be filtered based on their strain value. Furthermore, each exercise is inferred to belong to a specific workout day via inverse object properties, further enhancing the semantic relationships within the ontology.

Another compelling example of the role semantics play in the system's functionality is its ability to generate personalized workout plans that accommodate user-specific injuries. This capability was achieved by leveraging description logic (DL) assertions applied to specific subclasses of the `Planner` class. Central to this feature is a custom data property, `avoidsInjury`, which ensures the system generates safe and effective workout plans. The `avoidsInjury` property has a domain `Planner` and a range of the `Injury` class, which is used to contain specific injuries. By using this property, the system can filter out exercises that could potentially aggravate an existing injury, ensuring that users receive tailored and safe plans.

Project Website

Please visit our project website to view all of the information and related links that are discussed in this paper. **TODO CHANGE LINK ONCE IT IS MERGED TO MAIN.**

Limitations

One of the primary limitations of our implementation is the inability to provide the most optimized exercise recommendations tailored to specific injuries and fitness goals. Given the constraints of the length of the semester, our efforts were focused on defining goals, injuries, and workouts based on the basic intensity categories of light, moderate, and strenuous. Additionally, the ontology does not account for user-specific factors such as available equipment or preferences for certain types of workouts. Another intended feature of the ontology was to include meal recommendations alongside exercise plans. However, due to the limited timeframe, this functionality had to be removed to ensure a more focused scope. The ontology also does not have a way to track user progress allowing for users to reap the full benefits of an exercise plan that remains tailored through their own progress. Many of these limitations can easily be implemented into the ontology and are discussed more in the future work section.

Conclusion

The FitMe team believes that the system presented in this paper could positively benefit users seeking personalized workout recommendations. By considering individual goals and injury conditions the system offers tailored exercise plans that enhance both safety and effectiveness. While it cannot replace expert advice, it serves as a valuable tool for users at various fitness levels, from beginners to athletes. Looking ahead, integrating dynamic user progress tracking and advanced machine learning techniques could further improve the system's ability to adapt to individual needs. By adding a diet tracker and meal planner, it can completely personalize someone's physical health goals and needs. With continued refinement, FitMe has the potential to revolutionize how users approach personalized fitness and injury prevention.

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