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Ontology Engineering for Gastric Dystemperament in Persian Medicine

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Abstract

Objective Developing an ontology can help collecting and sharing information in traditional medicine including Persian medicine in a well-defined format. The present study aimed to develop an ontology for gastric dystemperament in the Persian medicine.

Methods This was a mixed-methods study conducted in 2019. The first stage was related to providing an ontology requirements specification document. In the second stage, important terms, concepts, and their relationships were identified via literature review and expert panels. Then, the results derived from the second stage were refined and validated using the Delphi method in three rounds. Finally, in the fourth stage, the ontology was evaluated in terms of consistency and coherence.

Results In this study, 241 concepts related to different types of gastric dystemperament, diagnostic criteria, and treatments in the Persian medicine were identified through literature review and expert panels, and 12 new concepts were suggested during the Delphi study. In total, after performing three rounds of the Delphi study, 233 concepts were identified. Finally, an ontology was developed with 71 classes, and the results of the evaluation study revealed that the ontology was consistent and coherent.

Conclusion In this study, an ontology was created for gastric dystemperament in the Persian medicine. This ontology can be used for designing future systems, such as case-based reasoning and expert systems. Moreover, the use of other evaluation methods is suggested to construct a more complete and precise ontology.

Keywords
- ontology development
- ontology evaluation
- Delphi method
- traditional medicine

Introduction

Traditional medicine refers to the knowledge, skills, and methods which originate from theories, beliefs, and local experiences of different cultures and employed to prevent, diagnose, treat, and cure mental and physical diseases. Traditional medicine comprises a wide spectrum of diagnostic and therapeutic methods which differ from country to country and region to region.[1] This field of medicine can play

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a major role in public health care due to its indigenous nature, easy access, and cost-effectiveness.[2] There are different types of traditional medicine, and Persian medicine is among the oldest one in the world, dating back to more than 1,000 years ago.[3] However, most of the information and methods of treatment in traditional medicine including Persian medicine are undocumented or provided in an informal format. As a result, developing ontologies has been suggested as an acceptable method for collecting and sharing information in a well-defined format.[4] The aim of ontology is to decrease conceptual and terminological confusions in a particular domain. It can also enable traditional medicine to be used in conjunction with other medical informatics applications, such as case-based reasoning (CBR) and expert systems.[5–7] Ontology is an explicit specification of a shared conceptualization which formally expresses the concepts, features, and relationships within a domain.[2] The ontology can also be used for semantic similarity measurement.[8]

Although there is no standard method for developing ontology, the Delphi method is one of the approaches suggested for this purpose.[9] The Delphi method has been widely accepted as an approach for collecting experts' opinions in a domain with the aim of reaching consensus on a specific problem.[10] This method is a structured process for collecting expert knowledge through completing questionnaires and receiving feedbacks on the responses of other participants.[11] This method has been used to develop ontologies for different domains including patient education documents,[12] assistive technology,[11] and tourist resorts.[13]

In Persian medicine, the digestive system, especially the stomach, is of high importance and the specialists prevent and treat stomach diseases to treat many other disorders.[14] Among stomach diseases, stomach dystemperament is diagnosed experimentally, as there are many exceptions and the specialists' diagnoses can be different based on their experiences and knowledge. In addition, the literature review showed that the research regarding the ontology development in Persian medicine was scarce.[5] Therefore, the present study aimed to create an ontology for gastric dystemperament in Persian medicine.

Methods

This was a mixed-methods study conducted in 2019. Initially, qualitative methods including literature review and expert panels were used to identify the main concepts and their relationships. Then, the Delphi method was applied as a quantitative method to validate the results. Before conducting the research, the ethical approval was obtained (IR.IUMS.REC.1397.440). ►Fig. 1 shows the research stages of ontology development.

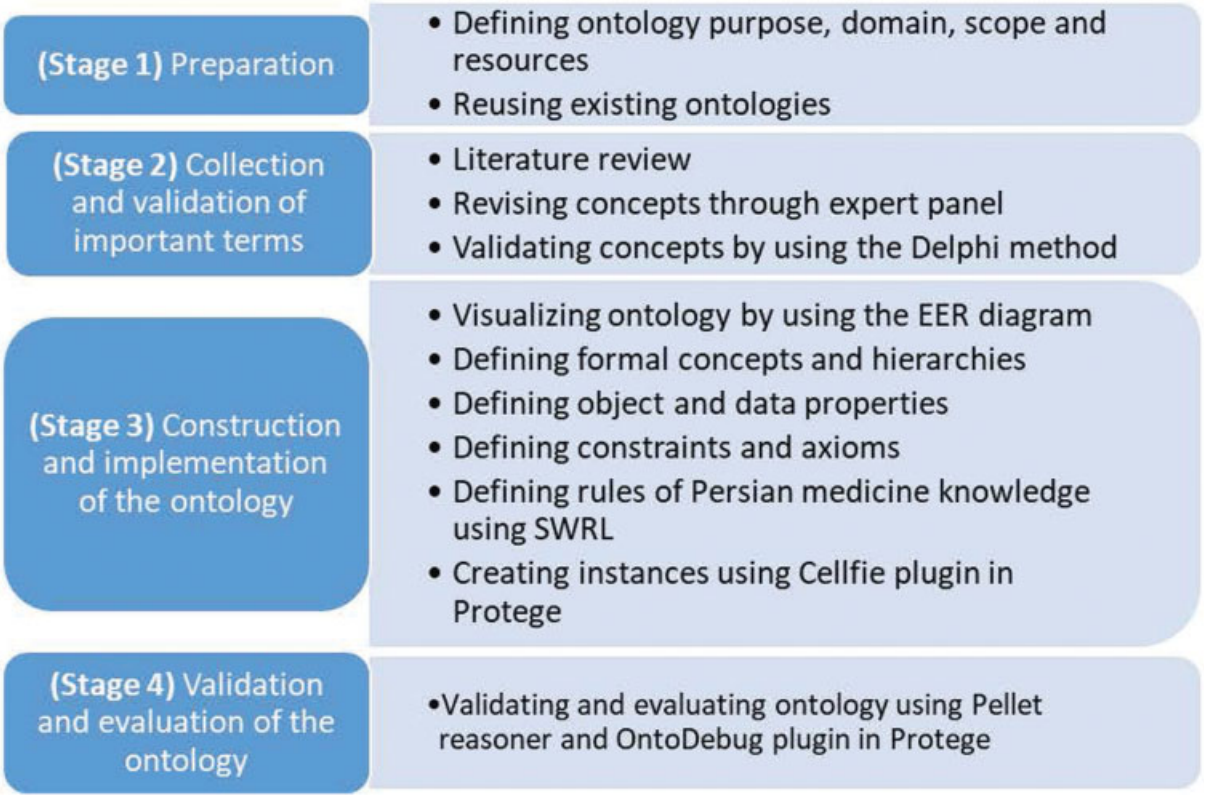

Fig. 1 Stages of ontology development.

Stage 1: Preparation

At the beginning of ontology development, several fundamental questions (e.g., the purpose of ontology development, its domain, the data that must be provided, and the main sources for concept extraction) must be answered.[15,16] In addition, the possibility of reusing available ontologies[15] should be considered to reduce the time spent on its development and a list of important terms which are expected to be included in the ontology must be specified.[17,18] At this stage, it is also essential to create a set of competency questions (CQs) for ontology validation. A CQ is a question that an expert expects to find its answer by using a domain-specific knowledge base. Therefore, an ontology must contain necessary knowledge to represent and answer these domain-oriented questions.[19] Similarly, in the present study, an Ontology Requirements Specification Document (ORSD) for gastric dystemperament in Persian medicine was developed and other ontologies[20–23] were examined for their reusability in the current ontology.

Stage 2: Collection and Validation of Important Terms and Concepts

To collect the initial list of terms and concepts related to gastric dystemperament in the Persian medicine, the literature, including Persian medicine textbooks (Tib Akbari,[24] Exir-e-Azam,[25] Sharh Al-Asbab[26]) and relevant published papers were reviewed. To find the papers, PubMed, Web of Science, Scopus and the Science Information Database (SID) were searched. No time limit was set for searching the papers, and all papers were searched until the end of January 2019. The keywords included stomach, temperament, Persian medicine, gastric, dystemperament, mizaj, and traditional medicine which were combined with AND/OR operators. The search strategy is shown in ►Supplementary Appendix A, available in the online version only. In total, 33 papers were retrieved, and finally 13 papers were selected for extracting the concepts related to gastric dystemperament in the Persian medicine. The selected terms and concepts were given to the specialists for validation. Five Persian medicine specialists were selected by using a convenience sampling method and they shared their opinions in an expert panel. The content from the panel was digitally recorded, transcribed verbatim, and analyzed by using the content analysis method. Finally, based on the participants' opinions, modifications were made and some concepts were added or removed.

Then, the Delphi method was adopted for the validation and completion of the terms and concepts.[27] The Delphi questionnaire was a five-point Likert scale ("not important" [1] to "very important" [5]) and consisted of 241 concepts and 30 open-ended questions.

The purposive sampling method was used to recruit 25 Persian medicine specialists who had at least 2 years of work experience. In total, three Delphi rounds were conducted, and 16, 12, and 9 specialists participated in the first, second, and third rounds, respectively. In each round, those concepts that reached a consensus were included in the final ontology, and the remaining ones or the newly suggested ones were asked again in the next round. In this study, both percentage and median were considered to decide about reaching consensus. If more than 75% of the participants chose the first two options of the scale (very important and important) and the median was 4 or above, it was concluded that the consensus was reached and the concept would be included in the final ontology. Concepts with a consensus of <50% and a median of <3.5 were removed from the ontology, and the remaining ones were examined again in the next round of the Delphi study.

Stage 3: Construction and Implementation of the Ontology

At this stage, the ontology was constructed and implemented based on the concepts confirmed in the previous stage and by reusing available ontologies. Graphical notations were used to convert the collected informal terms into a conceptual model and an enhanced entity-relationship (EER) diagram was designed. The OWL2 language was used as the ontology language, and Protege 5.5 was employed as the ontology construction tool. Moreover, Pellet and OntoDebug plugins were used for evaluation, and Cellfie plugin was used for constructing instances in the ontology. Since the OWL2 ontology language cannot include deductive knowledge, i.e., rules,[19] the rules related to the knowledge of gastric dystemperament in Persian medicine were defined as another layer of the ontology. The rules were defined by the Semantic Web Rule Language (SWRL).

Stage 4: Validation and Evaluation of the Ontology

In this study, two methods were adopted for ontology evaluation. Initially, the Pellet reasoner was used to identify inconsistency errors in the ontology. The second evaluation method was using CQs proposed by Schekotihin et al.[28] They proposed a test-driven development method for ontology engineering which was inspired by software engineering. In this method, instances are defined for the test cases, and the ontology is expected to deduce these instances from the available knowledge. In the present study, test cases were defined based on CQs. Subsequently, by using the OntoDebug plugin, the consistency and coherence of the ontology were examined.

Results

In this section, the results of each stage of the study mentioned in the methods section are presented.

Stage 1: Preparation

Initially, ORSD and a list of available ontologies related to the target ontology were prepared. The ORSD included the objective, domain, implementation language, scope, knowledge sources, and CQs for the construction of gastric dystemperament ontology (►Table 1).

Stage 2: Collection and Validation of Important Terms and Concepts

The primary concepts were extracted from the textbooks and papers related to gastric dystemperament in the Persian

Table 1 Ontology requirements specification document

Domain	Medical, and more specifically, Persian medicine domain
Objective	To decrease conceptual and terminological confusions in a particular domain (gastric dystemperament). To be used for semantic similarity measurement in the future CBR systems.
Implementation language	OWL, supporting Persian and English language.
Scope	The most fundamental terms in the ontology included different types of dystemperament (simple dry, simple moist, etc.) diagnostic criteria (appetite, thirstiness, pulse status, etc.), and treatments for gastric dystemperament (healthy diet, laxative syrups, etc.). Diagnostic criteria contained different types of gastric dystemperament. Also, the rules related to the knowledge of gastric dystemperament in Persian medicine were added to the ontology.
Knowledge sources	Persian medicine textbooks and papers about gastric dystemperament.
Competency questions	What are the different types of gastric dystemperament? What criteria are used for diagnosing gastric dystemperament? What are the treatments for gastric dystemperament?

Abbreviation: CBR, case-based reasoning.

medicine. By searching databases, 33 papers were retrieved and entered into the EndNote software. After removing duplicates, titles and abstracts of the remaining 24 papers were examined based on the inclusion and exclusion criteria. According to the inclusion criteria, papers written in Persian or English language which dealt with diagnostic criteria and treatment methods for gastric dystemperament were included in the study. If the free full text of a paper was not available, the authors of the paper would be contacted via email. Finally, those papers with no full text available or irrelevant to the gastric dystemperament diagnosis and treatment were excluded, and 13 papers and three textbooks were selected for extracting the main concepts. As the textbooks were primary sources of Persian medicine,[24–26] the main concepts related to the diagnostic criteria and treatments of gastric dystemperament were extracted from them and only papers with new relevant concepts were selected for further review. As a result, the number of the selected papers was relatively small. The papers and textbooks were reviewed manually by two researchers (H.S.-M.) and (A.A.) and a list of concepts including diagnostic criteria and treatments for different types of gastric dystemperament was prepared. Then, five experts in Persian medicine were invited to participate in an expert panel and comment on the list of concepts. The demographic characteristics of the participants are presented in ►Table 2.

Table 2 The demographic characteristics of the participants in the expert panel

Variable		*N*	%
Sex	Male	1	20
	Female	4	80
Age	40–49	4	60
	≥50	1	20
Work experience (Years)	5–9	4	80
	≥10	1	20

The participants of the expert panel emphasized that the textbooks are the best source of information and one of them, namely Exir-e-Azam[25] included diagnostic criteria for gastric dystemperament. Another Persian medicine textbook (Tib Akbari)[24] was also suggested as a reference for identifying treatments. Moreover, they recommended considering a scale for some symptoms, such as appetite, and classifying them from "very low" to "very high" in future system development.

Based on the comments given by the expert panel, the list of preliminary concepts was revised, and a new list was prepared by the researchers (H.S.-M.) and (A.A.). The new list was approved by the expert panel and was subsequently validated by using the Delphi method in three rounds. In the first round, a questionnaire with 271 concepts was given to the Persian Medicine specialists and those concepts which did not reach a consensus were asked again in the next round. The demographic characteristics of the participants in the Delphi study are presented in ►Table 3.

In the first round, 16 concepts, including dropsy in simple moist dystemperament (3.45 ± 0.69, $n = 11$, 36.4%) and stomach pain in simple dry dystemperament (3.67 ± 0.98, $n = 15$, 46.68%) were removed from the list due to the low

Table 3 The demographic characteristics of the participants in the Delphi study

Delphi rounds Variables		Round 1 *N* (%)	Round 2 *N* (%)	Round 3 *N* (%)
Age	30–39	3 (18.75)	3 (25)	3 (33.33)
	40–49	11 (68.75)	7 (58.33)	4 (44.45)
	≥50	2 (12.5)	2 (16.67)	2 (22.22)
Sex	Male	2 (12.5)	2 (16.67)	2 (22.22)
	Female	14 (87.5)	10 (83.33)	7 (77.78)
Work experience (Years)	<5	3 (18.75)	2 (16.67)	2 (22.22)
	5–9	6 (37.5)	6 (50)	4 (44.45)
	≥10	7 (43.75)	4 (33.33)	3 (33.33)

level of agreement (<50%) and median (<3.5). While 178 concepts, such as benefiting from coolants in simple dry dystemperament (4.56 ± 0.51, $n = 16$, 100%), and drooling in simple hot and moist dystemperament (4.25 ± 0.93, $n = 13$, 81.25%) reached a consensus, the remaining 47 concepts did not reach a consensus and were asked again in the second Delphi round. Furthermore, 12 new concepts, e.g., stool softness for simple moist dystemperament were added to the concepts which were examined again in the second round of the Delphi study.

In the second round, marital status (3.33 ± 0.89, $n = 12$, 41.7%) was removed from the list upon the expert consensus, and 49 concepts reached consensus. The remaining nine concepts including the fast exit of food from the stomach in simple moist dystemperament (3.67 ± 0.49, $n = 12$, 66.7%) and poor appetite in phlegm dystemperament (4.08 ± 0.9, $n = 12$, 66.7%) entered the third round of the Delphi study, as they achieved a consensus between 50 and 75%.

In the third round, a questionnaire with nine concepts was given to 12 participants of the previous round. In this round, six concepts, including the fast exit of food from the stomach in simple moist dystemperament (4 ± 0, $n = 9$, 100%) and poor appetite in phlegm dystemperament (4.11 ± 0.78, $n = 7$, 77.7%) were added to the final list, and three concepts were removed upon the expert consensus. Finally, after three rounds of the Delphi study, 233 concepts were selected to be included in the ontology.

Stage 3: Construction and Implementation of the Ontology

At this stage, the ontology was constructed based on the results derived from the Delphi study. ►Fig. 2, shows the EER diagram of the ontology. As the authors planned to use the ontology in a CBR system in the future, initially, cases were defined and for each case (patient), a problem including different features and a solution including a diagnosis and a treatment were defined. Diagnosis contained a classification for dystemperament (moist, hot, cold, dry, hot and moist, hot and dry, cold and moist, cold and dry), type of dystemperament (excess humor, simple), and type of humor (black bile, phlegm, blood, and yellow bile). In total, 11 entities and 52 features were defined for the ontology (►Fig. 2). In fact, all of the diagnostic criteria were features for the future CBR system. In a CBR system the features are used for computing similarity between cases. The feature value could be numeric data (e.g., for the appetite level and age), string (e.g., for job and body state), Boolean (e.g., for saliva and stomach heaviness), ordinal (e.g., for flatulence), and concept (e.g., disease name).

As noted earlier, this study adopted a middle-out approach for the construction of the ontology. ►Fig. 3 presents the classes of the ontology. First, middle-level concepts, such as appetite, pulse, and demographic information were identified. Then, these concepts were classified in the form of high-level concepts and more details were expressed using low-level concepts like pulse power, appetite level, and age.

Relationships between classes were expressed by object properties, and class attributes are expressed by using data properties. ►Fig. 4 illustrates the data properties and object properties of the ontology.

After defining the concepts and the relationships between them, constraints were applied on the values and complex concepts were defined. For instance, values related to age and body mass index must be in the numeric format; sex and Face_Color were defined in the string format, and heartburn and hiccup values were in the Boolean format. For each of these, a range of properties was defined in terms of xsd: integer, xsd:string, and xsd:Boolean. Moreover, the cardinality constraint was constructed for the hasSolution property, meaning that each case must have one solution. Then, the rules related to the knowledge of Persian medicine for the diagnosis of gastric dystemperament were added to the ontology. In total, the ontology contained 71 classes, 57 instances, 60 object properties, and 15 data properties. It was uploaded to the Bioportal ontology repository.[29]

Finally, 88 medical records related to the patients with gastric diseases were selected. Then, the data were entered into the ontology and the Cellfie plugin was used to construct the instances.

Stage 4: Validation and Evaluation of the Ontology

In the present study, two methods were adopted to evaluate the ontology. Initially, the Pellet reasoner was used to examine any logical contradictions and inconsistencies in the ontology. After adding the Pellet plugin to Protege, the ontology was examined, and few inconsistency errors were identified and resolved. Inconsistency in ontology refers to the existence of an error which prevents reasoning. Reasoners minimize these errors and ensure the consistency of the ontology.[30] The detected errors were fixed, and this process continued until no more errors were found. The errors were structural, like loops in defining subclasses. Eventually, the results revealed that the ontology was logically consistent.

Then, the OntoDebug plugin was utilized to answer the CQs. Initially, the rules were defined by using SWRL for the CQs related to the diagnosis of gastric dystemperament. Then, values related to the features of case_01 were added to show the diagnosis of excess humor dystemperament. To verify this diagnosis, "Solution_01 hasDystemperament Type Dystemperament_Excess_Humor" was added to the test case and the ontology showed that the excess humor dystemperament was a diagnosis. Another test case was "Dystemperament_Cold Type Dystemperament" and tested whether cold dystemperament, which is a type of gastric dystemeprament in Persian medicine, was defined as a type of dystemperament in the ontology or not. Finally, the results of the ontology evaluation showed that it was consistent and coherent.

Discussion

Traditional medicine is an unstructured domain of medicine in which making diagnosis is highly dependent on the specialists' experiences. Traditional medicine specialists mainly rely on their previous experiences in diagnosing and proposing therapeutic procedures. However, suggested

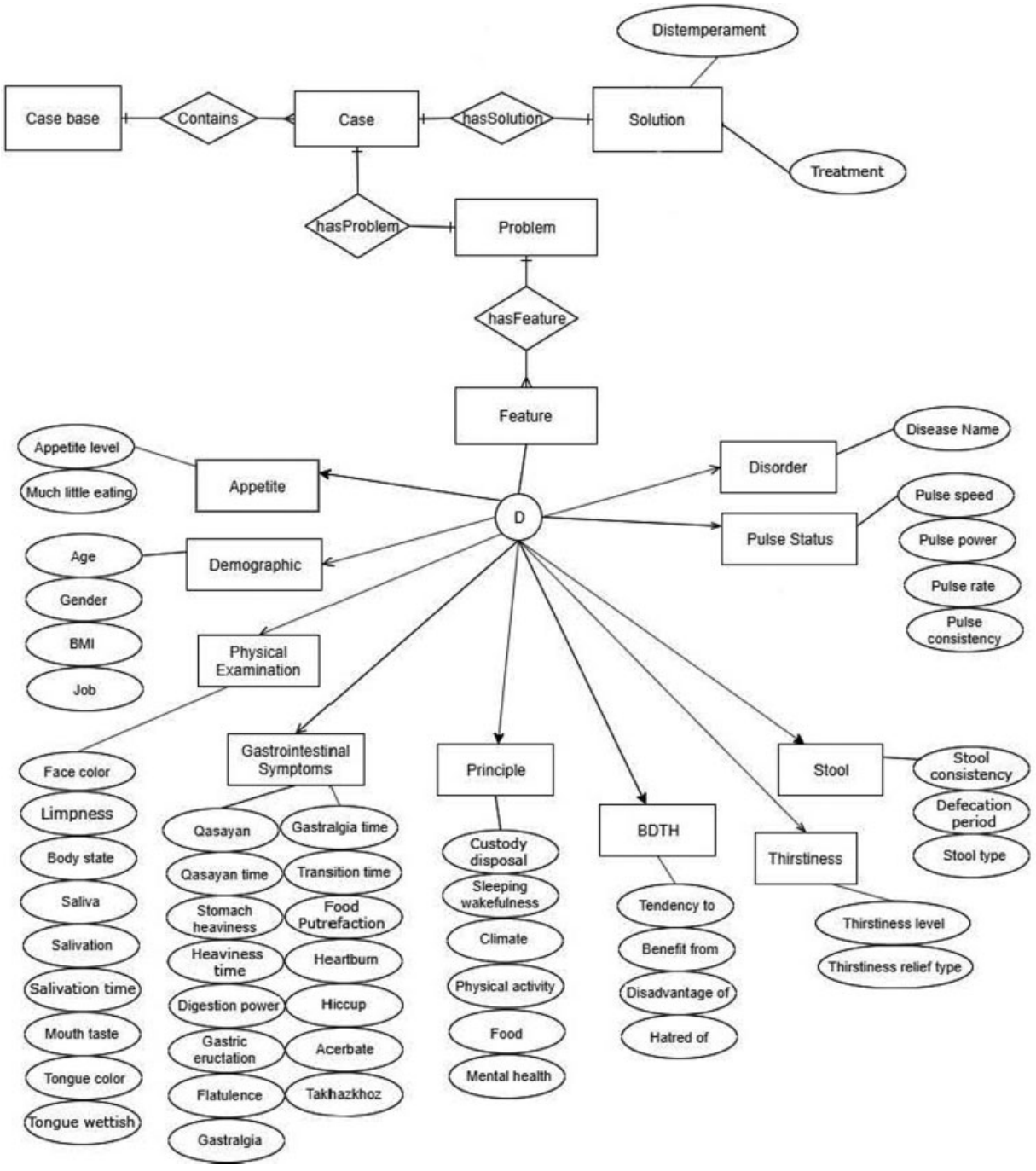

Fig. 2 EER diagram of the ontology. EER, enhanced entity-relationship.

diagnosis and treatment might be affected by intrinsic limitations of cognitive capacity of human beings, the power of memory, and recall. Therefore, the more we can improve the specialists' recall ability, the more the accuracy of diagnoses and treatments will be guaranteed.[31] Currently, several information systems have been developed in the field of traditional medicine to improve clinicians' performance. According to the literature, developing an ontology for these systems can improve various aspects of the system performance.[4] Ontology plays different roles for the semantics enhancement of different systems and covers case storage, representation, and reuse.[32] In addition, case semantic retrieval algorithms can be improved by using a case-base ontology and domain background knowledge.[33]

It is noteworthy that ontology development is a complex and labor-intensive process,[34] and various methodologies have been suggested to be used.[16,35] Nevertheless, there is no unified methodology for ontology development, and the existing methods suit different situations.[36] In the present study, a four-stage method for developing an ontology in the domain of Persian medicine was adopted. The first stage was related to providing an ontology specification document which included the requirements, objectives, and knowledge resources for determining the main concepts. This stage has

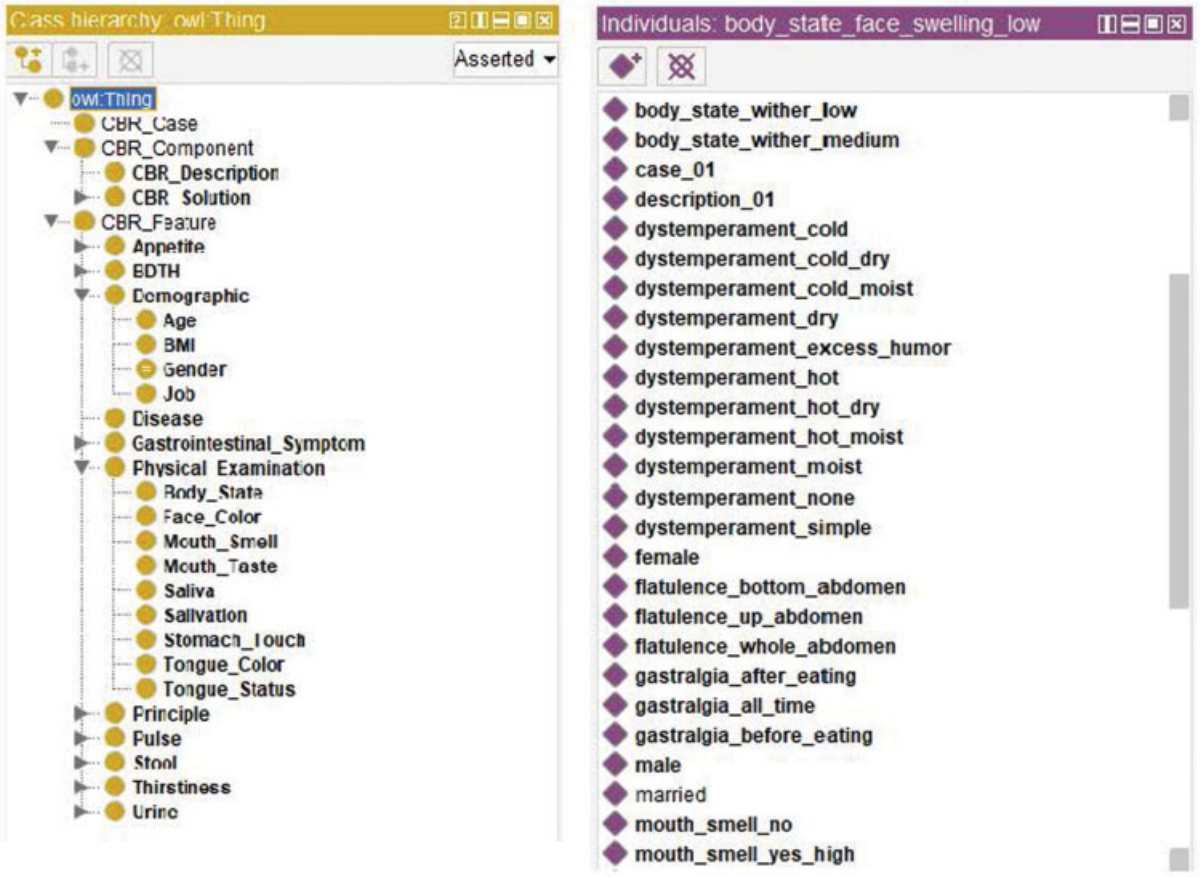

Fig. 3 The ontology classes.

been highlighted in most research related to ontology construction.[19,21,37] In the second stage, a comprehensive list of concepts, terms, and their relationships was prepared. This can be done by using brainstorming and examining textbooks, research articles, medical databases, existing ontologies, and medical guidelines.[19] The selected terms and concepts were then validated and finalized through conducting expert panels and the Delphi study. Similarly, the Delphi method was used in other ontology construction studies.[11–13] The Delphi method is a systematic method for the extraction and integration of informed judgments of a group of experts on a subject or question.[38] It also provides a criterion for consensus among experts, even when it is difficult to reach full agreement.[39] Although the results of the Delphi method can provide reliable and sufficient data for commencing ontology development, it cannot be claimed that this method completely covers the domain. After the use of ontology in the real world, some new concepts may emerge and must be added to the ontology in future.[12] Therefore, in the present study, a combination of methods including literature review, expert panel, and the Delphi method was used.

Ontology evaluation is another major point which seems to be neglected in the process of ontology development.[5] However, ontology evaluation helps to identify ontology problems and improves its development.[40] Ontology evaluation methods can be divided into two groups of syntactic and logic-based methods. In the syntactic approach, lexical structures of the ontology are examined, while in the logic-based approach, the accuracy of the knowledge modeled by the ontology is investigated.[28] From the syntactic viewpoint, the inconsistencies in the ontology can be discovered and rectified by using reasoners. From the logic-based viewpoint, the method proposed by Schekotihin et al[28] can be adopted by defining a set of test cases. In this method, a plugin called OntoDebug for Protege exists to perform all steps of the ontology evaluation and can provide an interactive environment for debugging.[40]

The most common approaches of ontology evaluation are the gold standard approach, task-based approach, data-driven approach, and criteria-based approach.[41] The criteria-based approach is divided into two groups of structure-based and expert-based approaches. Since CQs assess the performance of the ontology with a preliminary set of defined requirements, it can be regarded as a gold standard approach. Moreover, the examination of inconsistency errors in the ontology is a criteria-based approach (structure-based subcategory). It is notable that the ontology evaluation methods used in traditional medicine are categorized into three categories of expert-based evaluation, CQs, and

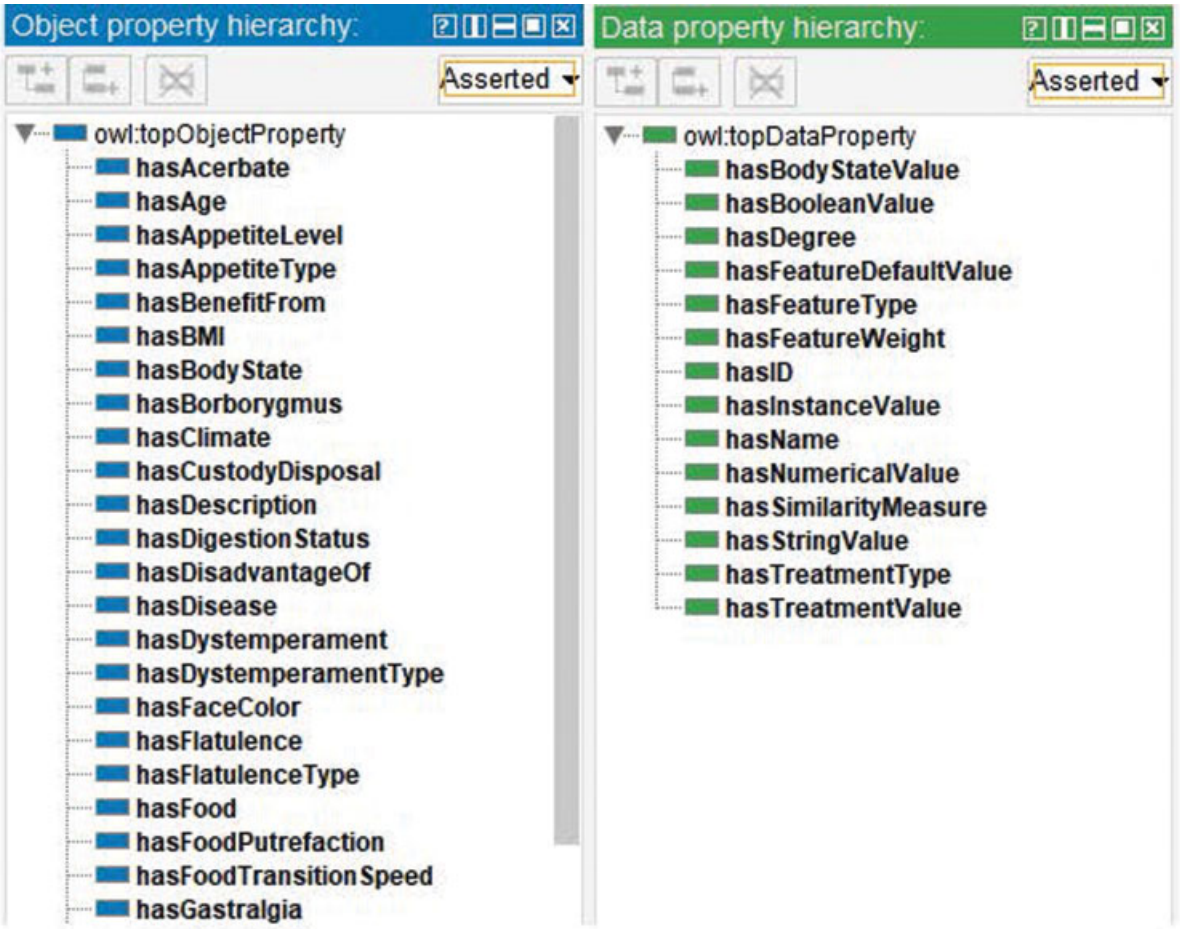

Fig. 4 Data and object properties.

automatic method. The most frequently used type of evaluation method is CQs followed by the expert-based evaluation method.[5] In the present study, due to the time and resource constraints and limited participation of the experts, the ontology was evaluated by using CQs and criteria-based approach. As the results of the ontology evaluation showed, it was consistent and coherent in terms of logic and CQs. Therefore, it seems that the ontology developed in the current study can be used in the future systems, such as decision support systems and CBR systems to give the best results in the area of gastric dystemperament in Persian medicine.

Research Limitations

This research had some limitations. First of all, the number of the participants in different stages of the research was limited, as the specialists were busy or reluctant to the subject of the study. However, those who participated in the study were well-experienced and familiar with the diagnostic criteria of, and treatments for gastric dystemperament. Moreover, extracting data from the paper-based medical records was difficult, as some records had a lot of missing data. Therefore, they could not be used and more complete records had to be searched and replaced.

Conclusion

In the present study, an ontology was constructed for gastric dystemperament in Persian medicine and various features were defined for different types of gastric dystemperament. Finally, the ontology was evaluated by using Pellet reasoner and OntoDebug to ensure its consistency and coherence. This ontology can be used for designing future systems, such as CBR and expert systems. Moreover, the use of other evaluation methods, such as expert-based evaluation, task-based evaluation, and data-driven evaluation are recommended to construct a more complete and precise ontology.

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Conflict of Interest

None declared.

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