View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by University of Liverpool Repository

Towards an Ontology to Identify Barriers to Physical Activity for Type 2 Diabetes

Yousef Alfaifi
Department of Computer Science
University of Liverpool, UK
Y.Alfaifi@liverpool.ac.uk

Floriana Grasso
Department of Computer Science
University of Liverpool, UK
Floriana@liverpool.ac.uk

Valentina Tamma
Department of Computer Science
University of Liverpool, UK
V.Tamma@liverpool.ac.uk

ABSTRACT

Type 2 diabetes is one of the most serious chronic diseases which can be managed by medication and lifestyle changes. Regular physical activity is an example of lifestyle modification that can help in managing and preventing complications of the disease. However, a number of *barriers* to physical activity of different origin and type (e.g. health, personal, and psychological barriers) can prevent patients from achieving their goals. Various studies have attempted to categories the different barriers, but there is no unified model representing the different barriers and the possible interactions between them and the patient's activities. In this paper, we propose a conceptual model to identify and classify the barriers to physical activity for type 2 diabetes that is intended lay the foundations for the development of an *ontology*, i.e. a formal model of barriers and their relationships with diseases and patient's activities. The proposed model relies on identifying and classifying the barriers to physical activity according to their signs or factors, and reuses existing formal models of diabetes and other open source specialised resources.

CCS CONCEPTS

• **Applied computing** → *Enterprise ontologies, taxonomies and vocabularies*;

KEYWORDS

Ontology; Type 2 Diabetes; Physical Activity

ACM Reference format:
Yousef Alfaifi, Floriana Grasso, and Valentina Tamma. 2017. Towards an Ontology to Identify Barriers to Physical Activity for Type 2 Diabetes. In *Proceedings of DH '17, London, United Kingdom, July 02-05, 2017,* 5 pages.
https://doi.org/http://dx.doi.org/10.1145/3079452.3079502

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
DH '17, July 02-05, 2017, London, United Kingdom
© 2017 Association for Computing Machinery.
ACM ISBN 978-1-4503-5249-9/17/07…$15.00
https://doi.org/http://dx.doi.org/10.1145/3079452.3079502

1 INTRODUCTION AND MOTIVATION

Diabetes is a chronic disease that occurs when the pancreas cannot produce enough insulin. It can also occur when the body cannot use insulin effectively, a condition known as insulin resistance. Consequently, the body is unable to regulate the amount of blood sugar and this can severely affect the lifestyle and the health of diabetic patients [3, 21]. The number of people living with diabetes jumped dramatically, reaching 422 million in 2014, compared with only 108 million in 1980 [21]. Forecasts predict this number will continue to rise to 552 million by 2030 [26] and 592 million by 2035 [14]. Treatment for diabetes and its complications costs about 10% of the total health budget annually. With the increase in diabetic patients, this cost could reach 17% by 2035. At least 90% of diabetic patients have type 2 diabetes (T2D), whilst the remaining 10% have other types (e.g type 1, gestational, etc.) [3]. This study focuses on only T2D, thus, the term diabetes herein refers to T2D.

Medications and lifestyle modifications have been effective in helping to manage this condition. Lifestyle changes include regular physical activity, healthy diet plans and weight management [3]. Regular physical activity, such as walking, jogging, swimming and cycling [21, 28], consists of any muscle-driven bodily movement that leads to energy expenditure, and helps the body to control blood sugar levels, by stimulating muscles to use glucose without using insulin [3]. Regular physical activity helps to manage T2D and to prevent undesirable complications [3, 21].

A number of barriers may prevent diabetic patients from performing regular physical activity. Most of these are common to both diabetic patients and the general population [3, 15]. Several studies have attempted to classify the different types of barriers: whilst the classifications tend to vary, the majority of studies identify *health*, *personal*, *psychological*, *social* and *environmental* barriers as the most recurring ones [4, 16, 17, 25, 28].

With this investigation we aim to build on existing specialised studies and we leverage on widely accepted vocabularies and classifications in order to build a formal and explicit model, (*an ontology*) that abstracts the possible barriers to physical activity, together with their interaction with patients' conditions and activities. An *ontology* is a conceptual model that allows experts and researchers to share the terms and concepts in a particular domain and the underlying assumptions and semantics. Ontologies play a vital role in medical health domain. They include machine-interpretable definitions that are used to provide an unambiguous account

of the terms used by a specific application within the medical domain. The ontology that we aim to build reuses and extends other existing ontologies, e.g. unified medical language system (UMLS) [6], to ensure interoperability with electronic health records (EHR) and other medical applications. In this paper we describe the model underlying the representation of barriers to physical activities, and provide an initial classification based on a review of exisitng studies.

The reminder of the paper is organised as follows: section 2 presents a classification framework of the barriers. Section 3 presents the proposed model to represent barriers. Section 4 discusses related studies, whilst Section 5 presents a brief discussion about moving from the proposed model to an ontology. Finally, section 6 presents a brief conclusion and potential future outcomes.

2 BARRIERS CLASSIFICATION FRAMEWORK

Barriers to physical activity have been extensively studied in preventive and diabetic medicine or in psychology, to name a few areas. A common effort of these studies aims to identify barriers to physical activity with the objective of promoting general well-being or as a preventive measures to manage chronic conditions such as diabetes, and T2D in particular [2, 4, 5, 7, 9, 17, 18, 28]. Whilst a few of these studies only list the barriers, without any attempt to classify them [10, 11], many have provided some form of categorisation based on a number of features or factors that support the direct or indirect identification of the barriers [4, 16, 17, 25, 28]. For example, the terms "*cold*" and "*windy*" both indirectly indicate barriers to optimal climatic conditions [16]. A few studies have accounted for factors in different regions, such as in Europe [4, 28], Australia [7], America [10] and Asia [16]. Environment, climate and weather conditions all play important roles in identifying the barriers to physical activity for T2D. These factors also guide the different identification and classification of barriers that result from different types of samples, either from the general population or from diabetic patients. These studies are the starting point for the analysis of the domain that is necessary in order to build an ontology of barriers. In order to be as comprehensive as possible we also include in our analysis studies that include the most common barriers and classifications of physical activity together with studies that describe unusual categories of barriers or that use rare terms.

Although these studies agree on most barriers and their categories, they still differ on some of them. Various factors affect the variations and classifications of these barriers, directly or indirectly. From our point of view, three essential reasons increase the problem of uncertain identification and classification of these barriers. The first reason is an incomplete classification of the barriers to physical activity for T2D. For example, lack of time constitutes a barrier, yet lacks sensible factors or signs to confirm it. These factors might include family commitments [7], childcare [18], work or study restrictions [2]. The second reason is using irregular terms to refer to the barrier, such as the term "*logistical*" as a variant of the term "*personal*" [17]. The third reason is an absence of a clear classification of the barriers, either partly or wholly. In other words, sometimes no visible standard exists to categorise or measure the barriers. The worst misuse involves illogical classifications. For example, some studies classify "*emotional*" as a main barrier [5], where other studies classify "*emotional*" as a factor of psychological or mental barriers [11].

3 THE PROPOSED MODEL

Misunderstanding the barriers to physical activity for T2D has resulted in an array of terms and classifications for these barriers (section 2). Diabetic and other specialised studies have provided uniform terms and logical classifications for barriers [4, 16, 17, 25, 28]. This provides the possibility of representing this knowledge domain in a specific scope. Ontology is one available conceptual model able to represent and classify the barriers conceptually.

Subsequently, the above reasons can cause misunderstandings, or worse, incorrect decisions about the barriers that result from uncertain and incomplete identification of them. In addition, it is a goal to present and emphasise the perceived barriers rather than assigned barriers. For example, we could classify "time restriction" as a psychological barrier [5, 29] or as a personal barrier [7, 18, 28]. At first glance, this is clearly an indistinct and confused classification. However, to overcome an ambiguous barrier classification like this, we need two things. First, we should establish uniform vocabularies to describe the main barriers. Therefore, the terms "health or physical", "psychological or mental", "environmental", "personal", and "social" all represent the most common vocabularies used to describe the main barriers (Table 1). Secondly, certain factors or features should identify the specific barriers [1]. Family or childcare responsibilities [7, 28] can be time restricting and thus, constitute the actual barrier (Table 1); otherwise, it is a perceived barrier [5].

Table 1 combines and summarises the different categories for physical activity barriers in the reviewed studies. The top row represents the main categories of barriers from the studies. The left column lists all common barriers derived from these studies. The "***X***" sign in the intersecting cells confirms a classification of each barrier column into one or more main barrier categories. The number of times patients mention barriers appears as a reference next to each barrier. Thus, the 1 proves the similarity of some terms that describe the same barriers, such as health and physical barriers, because these barriers (health and physical) have the same factors that identify them. This is also the case with psychological and mental barriers. Clearly, the main barriers are health or physical, psychological or mental, personal, social and environmental barriers (Table 1).

The proposed ontology model aims to identify and classify the common terms and concepts of physical activity barriers for T2D. This will give us a clear understanding and logical classification of the barriers. The branch of barriers forms

Table 1: Several classification of barriers to physical activity based on specialised studies [2, 4, 5, 7, 10, 11, 16, 17, 21, 25, 27–29]

	Health	Physical	Mental	Personal	Psychological	Logistical	Social	Environmental
Hypoglycemic [27, 28]	X [3, 17]				X [17, 28]			
Overweight/Obesity [21, 27]	X [17]	X [5, 17]						
Other disease [2, 21, 27]	X [7]	X [7]						
Time restriction [2, 10, 11, 16, 17, 17]				X [25]	X [2, 7, 29]	X [17, 28]		
Fear of hurting or injury [17, 20]		X [4]	X [4]		[2, 7]			
Lack of social support [2, 10]							X [2, 10, 17]	
Lack of safety [4, 12, 17, 29]								X [4, 17, 29]
Poor physical/health condition	X [7, 17]							
Lack of facilities (sidewalks) [4, 25]								X [7, 18, 28, 29]
Transport difficulties [5, 10]								X [10]
Changing jobs [5]				X [5]				
Financial problems [7, 28]				X [18]		X [17]		
Pain [10]	X [17]	X [4]	X [4]					
Decreased endurance and balance [4]		X [4]	X [4]					
Lack of company or partner [28]					X [7, 29]		X [5, 7]	
Dislike or unfamiliar [4]			X [4]	X [4]				
Emotion [5]					X [5, 11, 29]			
Feel depressed [28]			X [4]		X [5, 28]			
Lack of fitness or energy [2]	X [2]	X [2]						
Bad weather [2, 10, 17, 28]								X [4, 29]
Lack of motivation [5, 7, 12, 20]					X [2, 7, 29]			
Poor access [7, 10]								X [17, 25, 28]
Inactive or lazy [21]					X [5, 5]			
Others activities/priorities [2, 25, 28]				X [4]	X [2]			
Heavy traffic or Difficult parking [28]								X [4, 25, 29]
Climatic conditions [7]								X [16, 29]
Lack of enjoyment [17, 25, 28]					X [29]			
Poor body image [5, 17]		X [17]			X [5, 29]			
Health problems [10, 11, 17, 20]	X [7, 10]	X [7]			X [7]			
Cost of equipments [7, 17, 20, 28]								X [17, 25, 29]
Lack of self-efficacy [17]					X [29]			X [17]
Tired [25, 28]		X [29]						
Lack of family support [2, 11, 20]							X [29]	
Fear and shame [16, 17]					X [16, 17]			

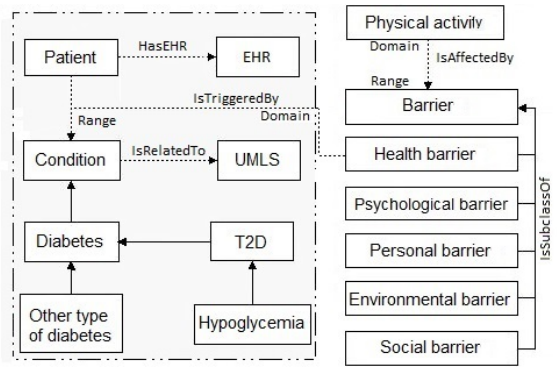

Figure 1: Framework for Barriers Classification

the backbone of the model. Its goal is to classify the barriers based on their signs or factors. It includes five main barriers: health or physical, personal, psychological or mental, social, and environmental barriers. The barrier's category links to the patient's condition (class) via the "IsTriggeredBy" property. The condition's class aims to capture the health barriers from different health domains. It links to three subcategories: diabetes, patient and biomedical ontology. The diabetes subclass aims to identify the barriers in the diabetic domain, such as the hypoglycaemia or brittleness barriers. The patient subcategory will import the medical record ontology, such as electronic health records (EHR).

The approach of Al Rector and other authors [24] suggests mapping the EHR information and corresponding links. In addition, the patient's class aims to link the EHR data with the condition's class via the "HasCondition" link. Clearly, the patient's condition determines the health barriers, not the patient. Consequently, the patient's class is outside of the scope of this paper.

The patient's condition also connects with biomedical ontology such as UMLS via the "IsRelatedTo" property. This provides mapping to various vocabularies and terminology systems. The shaded square on the diagram's left represents importing health barriers from several health domains, as mentioned above. The physical activity domain aims to model the patient's desired behaviour with specific physical activity. Furthermore, it determines the barrier's effect on physical activity. Thus, we contend that conditions such as diabetes (hypoglycaemia) or other health diseases affect the performance of regular physical activity, such as walking or jogging (Fig 1). The "IsAffectedBy" property shows the relationship between a barrier's class and the condition's class. The arrow's direction (the dotted arrow) remains a conflicting relationship because the behaviour establishes the condition, yet the condition also affects it.

4 RELATED WORK

A number of studies have explored managing diabetes through lifestyle changes. Ontology models is example of these developmental studies. Studies on physical activity are very rare compared with those addressing other types of lifestyle changes such as health and nutrition. This means the ontology field for physical activity still needs further research. Clearly, physical activity studies should include the barriers, recommendations and other elements. The paragraphs below summarise some of the related studies.

The authors in [23] develop an ontology based on a recommended system to manage diets for diabetic patients. The ontology can generate a diabetic nutrition plan based on patient conditions.

The authors classify food using 20 nutrients as attributes. Carbohydrates, energy, fat, protein and vitamins E and C are examples of these categories. The results of the system show improved accuracy and performance to produce a recommended diet plan for patients with diabetes.

Similarly, the authors in [8] create a food ontology as part of the PIPS (Personalised Information Platform for Health and Life Services) project. The system is able to determine the type and amount of nutrients, and the daily requirements of the suggested diet plan. The authors use the "Ontology 101 development process" by Noy and McGuiness [19] to develop this food ontology. The food ontology includes 177 classes, 53 properties and 632 instances.

The authors in [22] present a recommended exercise system based on ontology. The main goal of the system is to classify the diabetic patient's conditions and then produce a suitable physical activity for the patient. The system determines the physical activity based on the patient's medical evaluations. These evaluations include age, daily activities, food intakes and other factors. The resulting advice involves the intensity, frequency and duration for the suggested physical activity. The system's knowledge bases come from the American Diabetes Association (ADA).

5 DEVELOPMENT OF THE ONTOLOGY

A number of methodologies can help develop an ontology from scratch [13, 19, 30]. The "Ontology Development 101" paper by Noy and McGuinness will serve to develop the proposed ontology in the future. It is the most appropriate methodology for the suggested model because it provides a logical and clear sequence that enables a non-expert to understand it. The main barriers in the proposed model will be concepts (classes) in the ontology. The categories of barriers, such as lack of time and windy weather, will become a subclasses or properties, respectively, in the ontology. Existing medical ontologies such as UMLS and EHR could link with the suggested ontology by importing health barriers. A new extended ontology (physical activity) would serve to give a list of suggested exercises to patients. Naturally, this advice will draw from other related classes such as the class of barrier and also the patient's current health condition. The relationships between the classes, such as the "IsTriggeredBy" property, play a role in developing the ontology.

6 CONCLUSION AND FUTURE WORK

Managing and preventing complications of T2D by lifestyle changes poses a problem not only for individual patients but

also for health providers. Physical activity is one type of lifestyle modification. Diabetic patients often understand the value of physical activity to manage the disease, but barriers prevent them from performing physical activity. Filtering several terms and classifications of the barriers from related studies will lead to a deeper understanding of the barriers. After that, establishing uniform vocabularies and categories will result from recognising the actual barriers rather than perceived barriers. Fixed domains, scopes, detected barriers, sub-barriers and the relationships among them will all lead to a model to enhance the ontology in the future. Importing other medical ontologies, such as UMLS and EHR, can increase both the value and reliability of the future ontology.

Developing the main proposed ontology (pertaining to barriers) would be the next step. Understanding the UMLS and EHR data will help create links with the main ontology. In addition, designing a model of physical activity behaviour could be the starting point to expand this ontology in the future. Consequently, translating the ontology in this study from one form to an exportable form would not be difficult. This would allow moving from one ontology to another. Assessment methods, samples of diabetic patients, or both methods can help evaluate the proposed ontology.

Whilst the model is focussed on T2D, the general approach, and hence the basic structure of the ontology of barriers, can be generalised to a number of conditions, and in general to all situations in which one seeks to model motivation and motivational advice, and therefore constitutes a contribution to the general field of persuasive technology, argumentation, and adaptive system modelling.

REFERENCES

[1] Yousef Alfaifi, Floriana Grasso, and Valentina Tamma. 2016. Developing a Motivational System to Manage Physical Activity for Type 2 Diabetes. *Artificial Intelligence for Diabetes* (2016), 22.

[2] Kenneth R Allison, John JM Dwyer, and Susan Makin. 1999. Perceived barriers to physical activity among high school students. *Preventive medicine* 28, 6 (1999), 608–615.

[3] American Diabetes Association et al. 2016. Standards of medical care in diabetes-2016. *Diabetes care* 39, Supplement 1 (2016), S1–S112.

[4] Hilary J Bethancourt, Dori E Rosenberg, Tara Beatty, and David E Arterburn. 2014. Barriers to and facilitators of physical activity program use among older adults. *Clinical medicine & research* 12, 1-2 (2014), 10–20.

[5] Stuart JH Biddle and Nanette Mutrie. 2007. *Psychology of physical activity: Determinants, well-being and interventions*. Routledge.

[6] Olivier Bodenreider. 2004. The unified medical language system (UMLS): integrating biomedical terminology. *Nucleic acids research* 32, suppl 1 (2004), D267–D270.

[7] Michael L Booth, Adrian Bauman, Neville Owen, and Christopher J Gore. 1997. Physical activity preferences, preferred sources of assistance, and perceived barriers to increased activity among physically inactive Australians. *Preventive medicine* 26, 1 (1997), 131–137.

[8] Jaime Cantais, David Dominguez, Valeria Gigante, Loredana Laera, and Valentina Tamma. 2005. An example of food ontology for diabetes control. In *Proceedings of the International Semantic Web Conference 2005 workshop on Ontology Patterns for the Semantic Web*. 1–9.

[9] Catherine B Chan, Daniel AJ Ryan, and Catrine Tudor-Locke. 2006. Relationship between objective measures of physical activity and weather: a longitudinal study. *International Journal of Behavioral Nutrition and Physical Activity* 3, 1 (2006), 21.

[10] Gareth R Dutton, Jolene Johnson, Dori Whitehead, Jamie S Bodenlos, and Phillip J Brantley. 2005. Barriers to physical activity among predominantly low-income African-American patients with type 2 diabetes. *Diabetes Care* 28, 5 (2005), 1209–1210.

[11] Deborah Erickson. 2013. Barriers to physical activity in people with type 2 diabetes enrolled in a worksite Diabetes disease management program. *The Diabetes Educator* 39, 5 (2013), 626–634.

[12] Centers for Disease Control, Prevention, et al. 2011. Strategies to prevent obesity and other chronic diseases: The CDC guide to strategies to increase physical activity in the community. *Atlanta, GA: US Department of Health and Human Services* (2011).

[13] Thomas R Gruber et al. A translation approach to portable ontology specifications. *Knowledge acquisition* 5, 2 (????).

[14] N Hex, C Bartlett, D Wright, M Taylor, and D Varley. 2012. Estimating the current and future costs of Type 1 and Type 2 diabetes in the UK, including direct health costs and indirect societal and productivity costs. *Diabetic Medicine* 29, 7 (2012), 855–862.

[15] Eveliina E Korkiakangas, Maija A Alahuhta, Päivi M Husman, Sirkka Keinänen-Kiukaanniemi, Anja M Taanila, and Jaana H Laitinen. 2011. Motivators and barriers to exercise among adults with a high risk of type 2 diabetes–a qualitative study. *Scandinavian journal of caring sciences* 25, 1 (2011), 62–69.

[16] Julia Lawton, N Ahmad, L Hanna, M Douglas, and N Hallowell. 2006. I can't do any serious exercise: barriers to physical activity amongst people of Pakistani and Indian origin with Type 2 diabetes. *Health education research* 21, 1 (2006), 43–54.

[17] LP Lidegaard, Nete Schwennesen, Ingrid Willaing, and Kristine Færch. 2016. Barriers to and motivators for physical activity among people with type 2 diabetes: patients' perspectives. *Diabetic Medicine* 33, 12 (2016), 1677–1685.

[18] Anna Moschny, Petra Platen, Renate Klaaßen-Mielke, Ulrike Trampisch, and Timo Hinrichs. 2011. Barriers to physical activity in older adults in Germany: a cross-sectional study. *International Journal of Behavioral Nutrition and Physical Activity* 8, 1 (2011), 121.

[19] Natalya F Noy, Deborah L McGuinness, et al. 2001. Ontology development 101: A guide to creating your first ontology. (2001).

[20] Woon May Ong, Siew Siang Chua, and Chirk Jenn Ng. 2014. Barriers and facilitators to self-monitoring of blood glucose in people with type 2 diabetes using insulin: a qualitative study. *Patient preference and adherence* 8 (2014), 237–246.

[21] World Health Organization et al. 2016. Global Report on Diabetes. Geneva: World Health Organization; 2016. (2016).

[22] Djoko Pramono, Nanang Yudi Setiawan, Riyanarto Sarno, and Mohamad Sidiq. 2013. Physical activity recommendation for diabetic patients based on ontology. In *7th International Conference on Information & Communication Technology and Systems*. 27–32.

[23] B RajKumar and K Latha. 2015. DFRS: Diet Food Recommendation System for Diabetic Patients based on Ontology. *International Journal of Applied Engineering Research* 10, 55 (2015), 2765.

[24] Alan L Rector, Rahil Qamar, and Tom Marley. 2009. Binding ontologies and coding systems to electronic health records and messages. *Applied Ontology* 4, 1 (2009), 51–69.

[25] Jo Salmon, Neville Owen, David Crawford, Adrian Bauman, and James F Sallis. 2003. Physical activity and sedentary behavior: a population-based study of barriers, enjoyment, and preference. *Health psychology* 22, 2 (2003), 178.

[26] Jonathan E Shaw, Richard A Sicree, and Paul Z Zimmet. 2010. Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes research and clinical practice* 87, 1 (2010), 4–14.

[27] Ronald J Sigal, Glen P Kenny, David H Wasserman, Carmen Castaneda-Sceppa, and Russell D White. 2006. Physical activity/exercise and type 2 diabetes. *Diabetes care* 29, 6 (2006), 1433–1438.

[28] N Thomas, E Alder, and GP Leese. 2004. Barriers to physical activity in patients with diabetes. *Postgraduate medical journal* 80, 943 (2004), 287–291.

[29] Stewart G Trost, Neville Owen, Adrian E Bauman, James F Sallis, and Wendy Brown. 2002. Correlates of adults' participation in physical activity: review and update. *Medicine and science in sports and exercise* 34, 12 (2002), 1996–2001.

[30] Michael Uschold and Martin King. 1995. *Towards a methodology for building ontologies*. Citeseer.