

Opinion Mining and Sentiment Analysis of Online Drug Reviews as a Pharmacovigilance Technique

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Abstract— Pharmacovigilance is the science that focuses on identification and characterization of adverse effects of medications in populations when released to market. The focus of this paper is to study the prospects of exploiting drug related online reviews contributed by social media groups for finding the adverse effects of drugs using opinion mining and sentiment analysis. The experiences and opinions related to drug adverse reactions by patients or other contributors in these forums can be mined and analyzed as a facilitator for pharmacovigilance. This review paper highlights the usability of opinion mining and sentiment analysis as one of the approaches for pharmacovigilance.

Keywords- Pharmacovigilance, Opinion mining, Sentiment analysis, Drug reviews, Social media, User-generated content, Discussion forums, Health forums, Medical forums, Discussion forums, Adverse drug events, Adverse drug reactions, Side effects.

I. INTRODUCTION

The Web has become a big source of medical and health related information and high percentage of people are looking to Internet for health information. The social media networks in health domain are available in different forms, such as, review forums, discussion forums, blogs, microblogs, podcasts, wikis etc. This set-up, earlier coined as Health2.0, has been defined as “the use of social software and its ability to promote collaboration between patients, their caregivers, medical professional and other stakeholders in health” [1]. In their review paper, Grajales et al. specifically categorized 10 types of platforms on social media which are generating health related information as shown in Table 1 [2].

Pharmacovigilance (abbreviated PV or PhV) is the science relating to the recognition, assessment, understanding and deterrence of adverse effects, particularly long term and short term side effects of medicines [3]. Pharmacovigilance,

also called sometimes drug safety-monitoring, focuses on identification and characterization of adverse effects of medications in populations when released to market and it has traditionally relied upon databases of spontaneous reports mostly identifying those adverse events which occur in close proximity to drug use, and are relatively insensitive [4]. However, now a day, the huge user generated content is available on the drug review forums and can be explored for the assessment of new or unknown adverse drug events while medications are being used in wide populations. By focusing on mining the online drug review forums to get opinions/ sentiments/ reviews about behavior of drugs while they are being used in the market, can help conducting pharmacovigilance in a way different from the traditional methods.

Table 1. Categories of Social Media in Health Domain [2]

Sr.No.	Social Media Category	Examples	Functions/Services
1	Microblogs	Twitter	In medical education, for health service delivery, as hash-tags for particular discussion or topic on health issues
2	Social Networking Sites	Facebook	To form self-aggregated interest groups on specific medical conditions diseases, treatments, drugs etc.
3	Blogs	Wordpress	Medical bloggers with often highly educated professional sharing practical knowledge.
4	Professional Networking Site	Linkedin, Sermo, Asklepios, Doctors' Hangout, Ozmosis, Doc2Doc	Try to recreate the intimacy of the “physicians’ lounge” in an online environment.
5	Wikis	Wikipedia	Medical wikis used as starting point of information in health domain.
6	Mashups	Healthmap	To provide APIs for functionality using medical mashups. which combine usually a very large variety of data sources and APIs.
7	Collaborative Filtering Sites	Digg, Delicious and Connotea	To get information on the latest outbreaks and health-related news in the communities.
8	Media Sharing Sites	Slideshare	As a resource for health knowledge translation, patient community building, health research and medical education.
9	Thematic Networking Sites	23andme, Telehelp, Health Informatics Forum, SocialRN	Focus on particular theme, e.g., Telemedicine, informatics, nursing, genomics.
10	Others, such as Multi-User Virtual Environments (MUVE)	Secondlife, CliniSpace, OpenSim, InWorld Solutions	Focus on medical education, simulation and psychiatric treatment.

II. SIGNIFICANCE OF PHARMACOVIGILANCE

Pharmacovigilance, a subset of pharmacoepidemiology¹, focuses on identification and characterization of adverse effects of medications in populations [5]. The drug adverse events after drug being in use amongst the real time populations may be different from those reported in clinical trials. Clinical trials are conducted in standardized conditions far from the real world of prescription and use, discrepancies in patient selection or treatment conditions and that may alter both the effectiveness and risks.

Every drug carries some type of risk, and it is quite possible for new information to be revealed after a drug is in use by greater number of users or patients [6]. An adverse drug event (abbreviated ADE) refers to any injury caused by the drug (at normal dosage and/or due to overdose) and any harm associated with the use of drug (e.g. stoppage of drug therapy). ADR (abbreviated ADR) can be defined as “an visibly harmful or unpleasant reaction, resulting from an intervention related to the use of a medicinal product, which forecasts hazard from future administration and warrants prevention or specific treatment, or alteration of the dosage regimen, or withdrawal of the product [7]. Adverse drug reactions are special type of adverse drug events. Adverse drug reactions are classified into six types by Edwards and Aronson [7]: dose-related (Augmented), time-related (Delayed), non-dose-related (Bizarre), dose-related and time-related (Chronic), withdrawal (End of use), and failure of therapy (Failure). Clearly there is a great importance of pharmacovigilance in the context of drug safety after drugs are made available in the market.

A. Regulatory Bodies for Drug Safety

The regulatory bodies or organizations play an important role to oversee the various aspects related to drug development and drug safety processes in a country. The industries of pharmaceuticals are considered to be one of the highly regulated industries around the globe. The regulatory bodies for drug safety usually perform the functions of pre-market review and post-market monitoring to ensure drug safety. Every country has some type of body which is entrusted with responsibility to frame and enforce the rules and regulations relating to drug development. These bodies issue the guidelines, deal with registration, licensing, production, labeling and marketing of pharmaceutical products [9]. Two very influential pharmaceutical regulatory agencies in this category are FDA and EMA.

Food and Drug Administration (FDA) is a regulatory body of United States and it has its own mechanism post-market monitoring for drug safety after drug being released and put into use [10]. FDA is responsible for protecting the public health by assuring the safety and effectiveness of human and veterinary drugs, biological products, medical devices, the nation’s food supply, cosmetics, and products that release radiations. FDA is also responsible for advancing the public health by helping to speed innovations that make medicines more effective, safer, and more affordable and by

helping the people get the correct information they need to use foods and drugs to maintain and improve their health [10].

European Medicines Agency (EMA), a decentralized agency of the European Union, is responsible for scientific evaluation of drugs developed by pharmaceutical companies which are used in European Union. This agency which started in year 1995 is located in London [11]. The EMA does coordinate ‘pharmacovigilance’ system regarding medicines for European Union and deals with any changes in the benefit-risk balance of drugs once in use.

Table 2 shows some leading countries with their respective pharmaceutical regulatory bodies.

Table 2. Some leading countries and their pharmaceutical regulatory bodies

Country	Name of Regulatory Body
Canada	Health Canada
India	Central Drug Standard Control Organization (CDSCO)
China	State Food and Drug Administration
UK	Medicines and Healthcare Products Regulatory Agency (MHRA)
Australia	Therapeutic Goods Administration (TGA)
Germany	Federal Institute for Drugs and Medical Devices
South Africa	Medicines Control Council
Brazil	Agencia Nacional de Vigilancia Sanitaria (ANVISA)
Japan	Ministry of Health, Labour & Welfare (MHLW)

The safety and quality of drugs made available to the public, identification of the flaws and strategies for improvement in the drug regulation, all these are ensured by regulatory authorities [12]. As far as drug safety is concerned, these drug regulatory bodies perform certain functions and take subsequent actions based on the pharmacovigilance reporting. There are many types of pharmacovigilance techniques that have been applied by the drug regulatory bodies and each technique having its own advantages and disadvantages. Though the automation of pharmacovigilance techniques have been applied in many cases, however, using the online community can contribute in a way the other traditional methods cannot. The online drug review forums mined to get the adverse drug behaviors for pharmacovigilance is an effort in this direction.

III. ONLINE DRUG REVIEW DATA SOURCES

There are many online communities enabling the users to contribute the online information as far as related to the drug usage. They provide a platform for the patients having similar experiences and situations to share information. The health reviews are treated differently from product reviews because of the technical aspects involved in the health domain. This leaves the user generated content on these health related online communities underexploited and under-utilized in this domain.

The different types of health review websites are found in the social media networks. The categories, such as, websites which are dedicated to drugs, providing information on drugs and comments from reviewers (drug reviews websites); websites which are providing medicine or health category (product reviews websites); websites in which opinions and experiences by users are expressed about a disease or a drug (medical forums or health forums) and websites which allow users to store and manage all their medical record, to review drugs and share it (personal health platforms) [8]. Table 3 lists some of these drug review websites.

¹ Pharmacoepidemiology, which borrows from both pharmacology and epidemiology, is the study of the uses and effects of drugs in well-defined populations.

Table 3. List of some drug-review websites

Sr. No.	Drug Review Website
1	http://www.druglib.com/drugindex/rating/
2	https://drugs-forum.com/
3	http://www.pharmacyreviewer.com/forum/
4	http://www.drugratingz.com/
5	http://forum.internationaldrugmart.com/drug-information-f5/
6	http://www.legaldrugreviews.com/
7	http://www.drugs.com/forum/
8	http://www.bluelight.org/vb/forums/16-Basic-Drug-Discussion
9	http://www.askapatient.com/
10	http://www.mayoclinic.com/health/hairloss/DS00278/DSECTION=treatments-and-drugs

A. Types of Drug Reviews

Three types of reviews related to drugs on the different online health media, namely structured reviews, semi-structured reviews and unstructured reviews, have been identified depending upon their structure and content by Goeriot et al. [13].

Structured Reviews:

There is structure in how the content and other relevant information is gathered from the reviewer. For example, the information on different aspects of the drugs and information about reviewer is gathered through an online form. Examples of structured reviews are shown in Fig. 1 with excerpts of reviews from online websites at www.druglib.com and www.askapatient.com.

Atenolol review by 62 year old male patient

Rating: ★★★★★

Overall rating: ★★★★★

Effectiveness: Ineffective

Side effects: Severe Side Effects

Treatment Info: Atrial Fibrillation

Condition / reason: Atrial Fibrillation

Dosage & duration: 25 mg taken daily for the period of 3 months

Other conditions: mild hypertension

Other drugs taken: warafin, lisinopril

Reported Results: none except...slowed heart rate. My afib was NOT diminished, but I assume the drug was helping keep my heart rate when in Afib down somewhat

Side effects: The 3 months I was on atenolol (25mg) I had verigo, short term memory loss, anxiety, and hearing issue. All except hearing went away when I switched to a different beta blocker, Joe Hare

Comments: once a day 25 mg

RATING	REASON	SIDE EFFECTS FOR ACCUTANE	COMMENTS	SEX	AGE	DOSAGE	ADDED
1	Mild Acne	During treatment, experienced back pain, ankle pain, dry lips, poor night vision, skin sensitivity to sunlight, and muscle pain in forearms. One month after course ended, experienced bloating, gas, diarrhea, dry eyes, dry hair, pale skin, dry skin, deep wrinkles, hair loss, brittle nails, fatigue, loss of smell, loss of taste, pain all over body, numbness and tingling in hands and feet. All of the above side effects continue 5 years later, as well as Irritubis, hearing loss, vision loss, headaches, premature menopause and more. Do not take this drug! It may cure acne, or it may not, and you can end up with permanent side effects which will affect your ability to function in life.	This drug is used as chemotherapy in lower dosages than what is being prescribed for acne. Side effects during the treatment are bad. Side effects after the treatment are even worse. The side effects continue to get even worse as you age.	F	35	6 months 40 mg 2X D	7/13/2015 Email
1	To clear my skin	Yes I have clear skin now, with the occasional spot. But I have felt into a deep depression, I feel lost in so many ways I was never a down or depressed person on the first place even when I had spots. I was OK, yes maybe some days I would look at my skin and think maybe stay into because I wanted it to look better before I went out but I was not depressed. Yes I got like every other side effects from dry lips, but the depression has hit me hard I have been off the Tablet for 3 months nothing seems to be getting better in a way maybe worse I am so worried and scared I wish I never went on this drug and was just normal. I hate my whole life and the life I am living can't even be called a life because it's not	This Tablet messed up my brain I am deply depressed.	F	16	5 months 50	6/30/2015

Figure 1. Excerpts of reviews from www.askapatient.com and www.druglib.com respectively (structured reviews)

Unstructured Reviews:

In unstructured reviews the information and reviews are embedded in the unstructured text and the relevant opinions about drugs are to be mined from that text. Fig. 2 shows the example of an unstructured review from a discussion forum.

Semi-Structured Reviews:

These kinds of reviews are lie in between structured and unstructured reviews in which some kinds of information about reviews or reviewers collected is in structured manner, however, the contents of reviews are in the form of unstructured text.

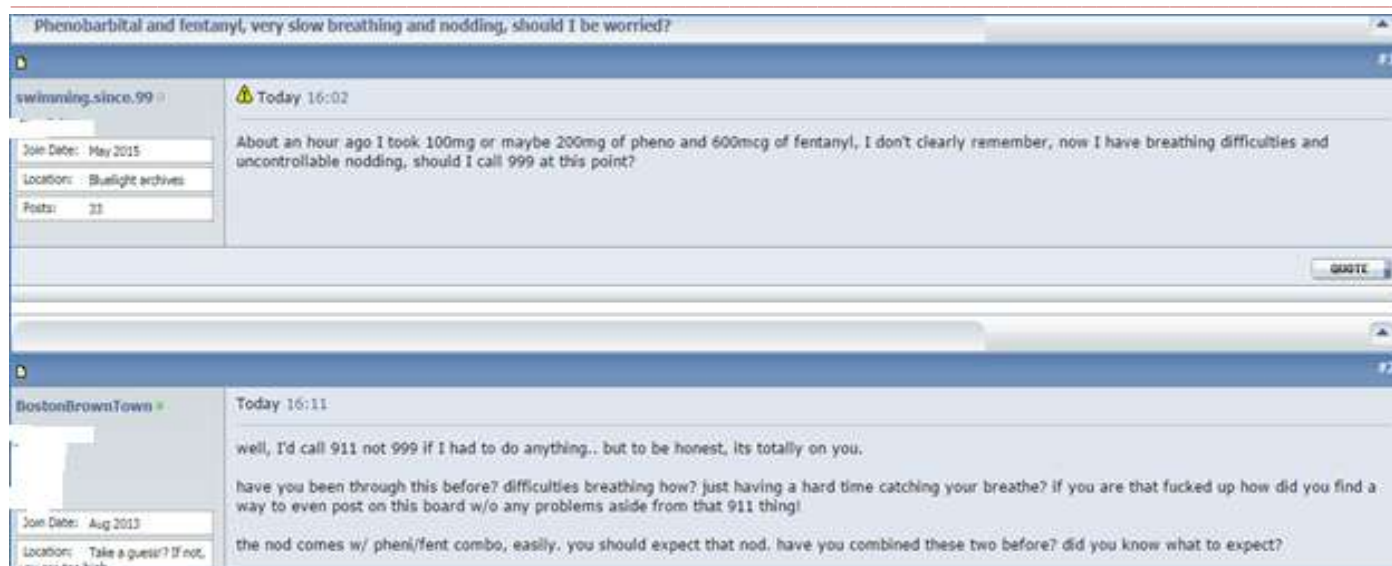


Figure 2. An excerpt of review from <http://www.bluelight.org/vb/forums/16-Basic-Drug-Discussion> (unstructured review)

IV. SOCIAL MEDIA FOR HEALTH RELATED ISSUES

The role of health professionals and offline resources is indispensable as far as health care is concerned, but this is a people increasingly are using online social tools to gather information, share stories, and discuss concerns about health related issues [14]. The social media networks like review forums, discussion forums, blogs, podcasts, and wikis are used to provide platform to the users for searching, contributing and editing content related to health, such as, about drugs, diseases, treatments, physicians, dieting, physical fitness and so on. Many surveys and studies have emphasized on the importance and use of social media for health related issues benefitting many stakeholders. The benefitted categories of users are not only the patients, their relatives, medical professionals, pharmaceutical companies, regulatory bodies etc. According to Benton et al. the patients who are being treated for serious ailments, due to anxiety about the long term use of drugs, turn to online communities for knowing about any potential side effects [15].

In a survey, conducted by Pew found that a huge percentage of population is utilizing health related online information for variety of purposes. The survey said 61% of American adult accessed information from online media for different diseases and treatments, and the major proportion of viewed information was user-generated [14]. In a comprehensive survey "Social media "likes" healthcare from marketing to social business" conducted in 2012 by Health Research Institute of PricewaterhouseCoopers (PwC), it was observed that 42% of consumers have used social media to access health-related consumer reviews [16]. Twenty nine percent of respondents have sought information related to other patients' experiences with their disease. Health activity on social media is expected to catch up non-health related activity in the future and it was further noticed that despite privacy concerns, many consumers are willing to share information via social media as they look potential of better insight to their health.

V. OPINION MINING FOR DRUG REPORTING

Opinions impact greatly our beliefs and perceptions of reality. Our behaviors and decision making gets influenced by the opinions of others. With the growing availability and recognition of opinion voicing resources such as online review sites, discussion forums, blogs, wikis etc., people actively use information technologies to look for and understand the opinions of others [17]. It has been established now that the user generated content from online social media contains valuable opinions of users in the domain of discourse and can be exploited for different types of applications.

Opinion mining or sentiment analysis is the computational study of sentiments, opinions, evaluations, attitudes, subjectivity, affects, appraisal, views, emotions, etc., expressed in the text accumulated from reviews, blogs, discussions, news, comments, feedback, or any other documents [18]. The sentiments or opinions of the reviewers may be based on their judgments, moods or evaluations and expressed about the overall contextual polarity of a document/review or about some aspects/features. Opinion mining has become a popular research topic in NLP, text mining, and Web mining in recent years. The information derived from opinion is subjective in nature and hence opinion mining is inherently difficult.

There has been a lot of research on opinion mining based on product reviews specifically targeting products, but the health related discussion forums provide a new prospect of doing opinion mining and sentiment analysis for pharmacovigilance. In one study by Colineau et al. [19], it was found that 85% of their survey participants were looking for their medical condition related information online. They assumed that information about ADRs is likely to appear on drug related online sites much before it reaches other data sources. It was observed that people often seek advice on adverse effects of some medications using social media rather than discussing it directly with their doctors.

Mao et al. [20] worked upon a large set of posts in cancer message boards to detect side effects for analyzing the frequency and associations of aromatase inhibitor drugs with

their side effects. In another study according to Liu et al. [21], the associations of prescription drugs, build upon the mined online reviews of patients, with potential side effect would be reality in the future and it would further consolidate the already existing sources. In a very relevant task related to pharmacovigilance by Yates and Goharian [22], Adverse Drug Events were extracted and matched with reported ADEs to find out any novel ADEs of breast cancer drugs.

Leaman et al. [23] observed in their work of finding association between drugs and side effects from online health related websites that the text irregularities are present in online text in the form of spelling mistakes, new and informal phrases, and other distortions of language. Karimi et al. [24] gave a new turn to the task of mining online patient forums by including both adverse as well as beneficial effects of drugs in one such work. In addition to these tasks of finding there are some efforts on also defining terms related to ADRS. In one of such tasks, Leaman et al. [23] combined some sources, such as, Coding Symbols for a Thesaurus of Adverse Reaction Terms (COSTART) [25], with a lexicon to extract ADR-related information.

In an interesting work, Chee et al. [26] observed that watch-list drugs are also a category of drugs talked about a lot in health forums and lot many opinions and sentiments can be found about these drugs. Goeuriot et al. analyzed the corpus of different kinds of user-generated reviews from three websites to identify which are the most-reviewed drugs and what was the vocabulary used [8]. They focused on opinion words, looked at many textual characteristics and also further analyzed the distribution of medical concepts in the corpus by performing semantic tagging with concepts from the UMLS metathesaurus. In another work Goeuriot et al. mined health-related social media content for identifying opinions about diseases and treatments [13]. They analyzed user-generated content on drug-related online sites and presented the textual analysis from linguistic and information points-of-view.

VI. POTENTIAL BENEFITS AND CHALLENGES

We can use the sentiment analysis on the drug behavior opined by users, usually patients, on the drug review forums to determine the adverse drug reactions and drugs classified in drug safety categories.

The information extracted by opinion mining from online drug reviews about Adverse Drug Reactions (ADRs) can be held in databases to allow for subsequent retrieval and analysis thereafter becoming the basis for drug safety monitoring. For example, the mined and processed knowledge of such kind could facilitate to better understand patterns of drug use amongst people. It could also be helpful in issues such as the adherence of patients to treatment prescribed by the doctors. This kind of harvested knowledge can be exploited for various studies under the purview of pharmacosociology. The novel findings from the mining of drug reviews about drug side effects can further become the basis of subsequent exploration, characterization and experimentation. If corroborated with the experimental finding, the countermeasures can be adopted to boost pharmacosociology. The other associated area of pharmacovigilance could get benefit, for example, the bodies examining the safe use of herbal or other non-allopathic medicines could be benefitted.

There are several challenges researchers have to face in extracting knowledge from online social media health related sources. The extraction of relevant knowledge from unstructured text is always been a challenging NLP task in itself, however, it becomes a bit more challenging when one is dealing with health documents especially online health discussion texts. The complexity in the task is amplified as there is a huge gap existing between health documents and patient vocabularies [27].

The language used in social media platforms is a way different from traditional language sources. The mistakes in the spellings, informal phrases and extensive use of non-standard abbreviations or grammatical structures are some of the problems in the case of social media texts [23]. Another challenge in the case of social media is to extract the relevant information as it might have to be dug out of high level of noise present in the text as the useful information might be hidden deep inside. Another challenge in this regard also lie in the fact that it is difficult to segregate out biases and confounding factors in the drug related reviews on social media platforms [28]. Further challenge is also there to handle temporal relationship between posts [15].

There have been concerns about the trustworthiness of the information available on these online health communities, however, when groups contribute to the collective intelligence the underlying assumption is that the content generated applies self-correction. Specific challenge in the case of drug related domain is that there are multiple factors could cause adverse drug effects. The demographics, drug-drug interactions due to simultaneous intake of many drugs and other specific factors are not that easy to isolate due to the missing information about these factors. In the end, analyzing and understanding the results might be challenging task in itself too.

VII. CONCLUSION

When people are confronted with a health decision such as use of medicines for treatment, social media can offer a new opportunity of information and discussion. The usage and importance of social media in the medical and health care domains has increased manifolds in the recent times. This upsurge has also raised many questions issues and challenges related to the role of online health content which need to be answered. The challenge is there in understanding of how social media can be effectively used in medical and health care. The issues are there to be dealt with role of social media in terms of principles, privacy, competence, control, and quality as far as health domain is concerned. This leaves the user generated content on these health related online communities underexploited and under-utilized in this domain.

The role of health professionals and offline resources is indispensable as far as health care is concerned, but people increasingly are using online social tools to gather information, share stories, and discuss concerns about health related issues. Though the automation of pharmacosociology techniques have been applied in many cases, however, using the online community can contribute in a way the other traditional methods cannot. The online drug review forums mined to get the adverse drug behaviors for pharmacosociology is an effort in this direction. The health related social media platforms provide a new prospect of doing

opinion mining and sentiment analysis for facilitating pharmacovigilance. The benefitted categories of users are not only the patients, their relatives, medical professionals, pharmaceutical companies, regulatory bodies etc. Many works done recently in this area of research underlines the importance and utility of opinion mining as one of techniques for pharmacovigilance.

REFERENCES

- [1] Sarasohn-Kahn, J. (2008). The wisdom of patients: Health care meets online social media.
- [2] Grajales III FJ, Sheps S, Ho K, Novak-Lauscher H, Eysenbach G Social Media: A Review and Tutorial of Applications in Medicine and Health Care J Med Internet Res 2014;16(2):e13
- [3] World Health Organization. (2002). The importance of pharmacovigilance.
- [4] Risk Sciences International. (2012). Ensuring Drug Safety and Effectiveness through Pharmacovigilance.
- [5] Martin, K., Bégau, B., Latry, P., Miremont-Salamé, G., Fourrier, A., & Moore, N. (2004). Differences between clinical trials and postmarketing use. *British journal of clinical pharmacology*, 57(1), 86-92.
- [6] U.S. Food and Drug Administration (2012). Advances in FDA's Safety Program for Marketed Drugs.
- [7] Edwards, I. R., & Aronson, J. K. (2000). Adverse drug reactions: definitions, diagnosis, and management. *The Lancet*, 356(9237), 1255-1259.
- [8] Goeuriot, L., Na, J. C., Kyaing, W. Y. M., Foo, S., Khoo, C., Theng, Y. L., & Chang, Y. K. (2011). Textual and informational characteristics of health-related social media content: A study of drug review forums.
- [9] Sengar G., Tripathy P (2011). Pharmaceutical Regulatory Agencies and Organizations around the World: Scope and Challenges in Drug Development. PharmaTutor.
- [10] Food and Drug Administration (FDA). 25 July 2015, date last accessed; Available from: <http://www.fda.gov/AboutFDA>.
- [11] European Medicine Agency (EMA). 25 July 2015, date last accessed; Available from: www.ema.europa.eu.
- [12] Masoni, M., Guelfi, M. R., Conti, A., & Gensini, G. F. (2013). Pharmacovigilance and use of online health information. *Trends in pharmacological sciences*, 34(7), 357-358.
- [13] Goeuriot, L., Na, J. C., Kyaing, W. Y. M., Khoo, C. S., Theng, Y. L., Chang, Y. K., & Foo, S. (2011). Textual and Informational Characteristics of Drug-Related Content on Three Kinds of Websites: Drug Review Website, Discussion Board and Hospital Information Portal. *International Journal of Organizational and Collective Intelligence (IJOICI)*, 2(3), 27-49.
- [14] Fox, S. (2011). *The social life of health information 2011*. Washington, DC: Pew Internet & American Life Project.
- [15] Benton, A., Ungar, L., Hill, S., Hennessy, S., Mao, J., Chung, A., ... & Holmes, J. H. (2011). Identifying potential adverse effects using the web: A new approach to medical hypothesis generation. *Journal of biomedical informatics*, 44(6), 989-996.
- [16] PricewaterhouseCoopers PwC. (2012). Social Media Likes Healthcare. Health Research Institute Report.
- [17] Pang, B., & Lee, L. (2008). Opinion mining and sentiment analysis. *Foundations and trends in information retrieval*, 2(1-2), 1-135.
- [18] Liu, B., & Zhang, L. (2012). A survey of opinion mining and sentiment analysis. In *Mining text data* (pp. 415-463). Springer US.
- [19] Colineau, N., & Paris, C. (2010). Talking about your health to strangers: understanding the use of online social networks by patients. *New Review of Hypermedia and Multimedia*, 16(1-2), 141-160.
- [20] Mao, J. J., Chung, A., Benton, A., Hill, S., Ungar, L., Leonard, C. E., ... & Holmes, J. H. (2013). Online discussion of drug side effects and discontinuation among breast cancer survivors. *Pharmacoepidemiology and drug safety*, 22(3), 256-262.
- [21] Liu, J., Li, A., & Seneff, S. (2011, October). Automatic drug side effect discovery from online patient-submitted reviews: Focus on statin drugs. In *Proceedings of First International Conference on Advances in Information Mining and Management (IMMM), Barcelona, Spain* (pp. 23-29).
- [22] Yates, A., & Goharian, N. (2013). ADRTrace: detecting expected and unexpected adverse drug reactions from user reviews on social media sites. In *Advances in Information Retrieval* (pp. 816-819). Springer Berlin Heidelberg.
- [23] Leaman, R., Wojtulewicz, L., Sullivan, R., Skariah, A., Yang, J., & Gonzalez, G. (2010, July). Towards internet-age pharmacovigilance: extracting adverse drug reactions from user posts to health-related social networks. In *Proceedings of the 2010 workshop on biomedical natural language processing* (pp. 117-125). Association for Computational Linguistics.
- [24] Karimi, S., Wang, C., Metke-Jimenez, A., Gaire, R., & Paris, C. (2015). Text and data mining techniques in adverse drug reaction detection. *ACM Computing Surveys (CSUR)*, 47(4), 56.
- [25] US Food and Drug Administration, & US Food and Drug Administration. (1995). COSTART: coding symbols for thesaurus of adverse reaction terms. *Publication NTIS PD*, 90-114026.
- [26] Chee, B. W., Berlin, R., & Schatz, B. (2011). Predicting adverse drug events from personal health messages. In *AMIA Annual Symposium Proceedings* (Vol. 2011, p. 217). American Medical Informatics Association.
- [27] Zeng, Q., Kogan, S., Ash, N., Greenes, R. A., & Boxwala, A. A. (2002). Characteristics of consumer terminology for health information retrieval. *Methods of information in medicine*, 41(4), 289-298.
- [28] Savage, N. (2012). Digging for drug facts. *Communications of the ACM*, 55(10), 11-13.