2016 15th International Conference on Ubiquitous Computing and Communications and 2016 8th International Symposium on Cyberspace and Security

Analysis of the Innovation Outputs in mHealth for Patient Monitoring

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***Abstract*—In the last decade, mobile health (mHealth) has developed as a natural consequence of the advances in mobile technologies, the growing spread of mobile devices, and their application in the provision of novel health services. mHealth has demonstrated the potential to make the health care sector more efficient and sustainable and to increase the healthcare quality. Considering the boost to the healthcare area which will be provided by mHealth, many organizations and governments have engaged in innovating in this area. In this context, this work investigated the role of innovation in the area of mHealth for patient monitoring in order to determine the trends and the performance of the innovation activities in this domain. Proxy indicators, like intellectual property statistics and scientific publication statistics, were utilized to measure the outputs of innovation during the period of time from 2006 to 2015 in Europe. Two studies were performed to provide quantitative measures for the indicators measuring innovation outputs in the domain of mHealth for patient monitoring and three main conclusions were observed. First, even if there was a lot of research in Europe in mHealth for patient monitoring, the vast majority of the enterprises did not protect their inventions. Second, a strong research collaboration in the area of mHealth for patient monitoring took place between researchers affiliated to institutions of different European countries and even with researchers working in Asian or American institutions. Finally, an increasing trend on the number of published articles about mHealth for patient monitoring was identified. Therefore, the findings of the studies demonstrated the great interest that has arisen the field of mHealth and the huge involvement in innovation activities in the area of mHealth for patient monitoring.**

I. Introduction

At the beginning of the new millennium, mobile health (mHealth) emerged as a branch of electronic health (eHealth). The novel advances in mobile technology, the growing spread of mobile devices and their innovative application in the provision of health services enabled the development of a new field named mHealth. The World Health Organization's (WHO) Global Observatory for eHealth defined mHealth in the 2009 Global eHealth survey [1] as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices". The European Commission (EC) extended the WHO's definition by adding that mHealth "also includes applications such as lifestyle and wellbeing apps that may connect to medical devices or sensors (e.g. bracelets or watches) as well as personal guidance systems, health information and medication reminders provided by SCMS and telemedicine provided wirelessly" in the Green Paper on mHealth [2].

Several international organizations and governments acknowledged the great potential of mHealth in order to boost the health sector, making it more efficient and sustainable, and increasing the healthcare quality. The "unprecedented" potential of mHealth was recognized by the United Nations in the Global Strategy for Women's and Children's Health launched in 2010 [3]. Therefore, this strategy included as a key innovation the use of mobile phones to achieve a better health. According to this approach, the WHO published in 2011 that mHealth has the potential to transform the health service delivery across the globe [1]. The WHO envisioned the potential of mHealth due to the following factors: the advances in mobile technology, the opportunities for the integration of mHealth into existing eHealth services, and the growth in coverage of mobile networks. The EC also recognized the potential benefits of mHealth in the Commission's eHealth Action Plan 2012-2020 [4] published in 2012. The Green Paper on mHealth [2] published by the EC in 2014, identified the potential of mHealth for the healthcare system and the market. This paper concluded that mHealth could be one of the key tools for tackling challenges, such as the aging of the population and the budgetary constraints, since it enables disease prevention and improves the system efficiency. Furthermore, the paper envisioned the creation of new businesses and of highly promising markets derived of the redesign of the healthcare provision.

In this context, this work aims at investigating the status and trends on mHealth innovations. Specifically, this work focuses on mHealth services devised for patient monitoring, that is mHealth monitoring systems built on mobile and portable sensor devices that are carried on, or directly worn, by their users. These devices are capable of measuring physiological and physical human characteristics such as vital signs or body motion. The recorded information is collected through a mobile phone application which acts as monitor. The main function of the mHealth monitoring system is to track the user health and behavior in order to determine abnormal

978-1-5090-5566-1/21 $31.00 © 6021 IEEE
DOI 10.1109/IUCC-CSS.2016.24

vital conditions, to quantify physical activity patterns and to support many other services. Therefore, this work contributes to the measurement of the innovation outputs in the domain of mHealth for patient monitoring.

II. Measuring Innovation

A. Motivation

Measuring innovation is fundamental due to its relation to the performance of enterprises, industries and the economy as a whole. Innovation has an impact on the turnover, market share, changes in productivity and efficiency of enterprises which are the key factors of their performance. Furthermore, at national level or at industry level, innovation has significant impact on international competitiveness, on total factor productivity, and on knowledge flow through networks. In fact, measuring innovation is of utmost importance to exploit and disseminate knowledge which is a central driver of the global economic growth and development. The measures of innovation are of relevance to have appropriate tools for the analysis of innovation and to reduce uncertainty in decision making. Enterprises need indicators to measure their performance in terms of innovation since innovation provides them a competitive advantage and is a keystone in their business strategy. Therefore, there is a need to capture innovation and to provide comprehensive indicators that measure it.

B. Background

During the 1980s and 1990s, a lot of work was undertaken to develop models and analytical frameworks for the study of innovation. The Oslo Manual [5], published by the Organisation for Economic Co-operation and Development (OECD) and the Statistical Office of the European Communities (Eurostat) in 1992, was the outcome of the analysis of early surveys on innovation and their results. The Oslo Manual has evolved in order to include new challenges and dimensions of innovation, until the actual version or third edition published in 2005. The Oslo Manual is one of the methodological manuals of the Frascati Family. The OECD Frascati Manual [6], first published in 1963 and its seventh edition available since autumn 2015, has become a world standard for Research and Development (R&D) measurement. The Oslo Manual provides guidelines for collecting and interpreting innovation data. In fact, the current version incorporates improvements on the measurement of innovation inputs and outcomes, as well as on the data collection methods. The Oslo Manual has become a reference for large scale surveys analyzing the nature and impact of innovation in the business sector, like the European Community Innovation Survey (CIS). Furthermore, countries outside the OECD region have undertaken surveys based on the Oslo Manual, which has become a worldwide reference for understanding innovation. Moreover, the OECD Science, Technology and Industry Scoreboard 2015 [7], which is a survey in which these principles have been applied, can be used to derive some ideas about the measurement of innovation.

C. Innovation Indicators

The indicators for measuring innovation have moved forward from innovation inputs to include the outputs and impacts of innovation. Innovation can be measured by quantitative indicators but it might also require a more qualitative analysis. The two best-known families of indicators to measure innovation are indicators of the field of science and technology, specifically, resources devoted to R&D and patent statistics. While R&D provides a measure of innovation input, inventive output is reflected in patents. In addition to these two basic families of indicators, innovation measurement can be complemented by several other indicators: statistics on scientific publications (bibliometrics), literature-based indicators of innovation output (publications in trade and technical journals), activity in high-technology sectors, and technology balance of payments. Apart from proxy indicators for the inputs and outputs of innovation, the impact of innovation can also be measured through innovation indicators. Such family of indicators measure the impact of innovation based on turnover, on costs and employment.

D. Indicators Measuring Innovation Outputs

The most promising innovation indicators measuring the outputs of innovation are intellectual property statistics, scientific publications statistics, and a combination thereof.

Intellectual property, mainly patents, are used as indicators of the output of innovation, since patent statistics are a proxy of technological innovations. Patent data, both applications and grants, provide information on the innovative capabilities of enterprises, and the number of patent granted reflects the technological dynamism of a firm or country. Moreover, the information contained in the patents enables the tracing of the origin of value creation, e.g., the geographical location of innovators and patent owners. The examination of the growth of patent classes can give some indication of the direction of technological change and of the intensity of innovation activities. The main drawbacks of utilizing patent statistics as indicator of innovation are that many innovations are not patented, some are covered by multiple patents, and some patents have no economic value at all.

Statistics on scientific publications, also known as bibliometrics, provide a partial measure of scientific production. Bibliometrics are based on the number of published documents in peer reviewed journals and indexed by data providers. The count of documents assigned to each of the different fields is an approximation of the trends in research and innovation. Moreover, calculating the median impact for each author provides a proxy of scientific impact. Finally, the number of citations of a publication can be utilized as a measurement of the excellence of scientific production. The main issues of utilizing bibliometrics as indicator of innovation is the bias introduced by indexing, as journal's classification may not provide an accurate representation of each document content.

The combination of statistics on intellectual property and on scientific publications provides a measure for the link between science and technology. An indicator of the knowledge flows between science and innovation can be obtained from the information contained in references to scientific literature as part of patented inventions. The share of scientific literature cited in patent families indicates the sources of prior scientific knowledge in patent documents.

In this work, intellectual property statistics and scientific publications statistics are utilized as innovation indicators. The main reasons for the selection of these innovation indicators is that they measure the outputs of innovation in a quantitative way and they had been used in state of the art analysis of well-known surveys. For example, in "World Corporate Top R&D Investors: Innovation and IP bundles" [8], the European Commission's Joint Research Centre (JRC) and the OECD investigates the innovative output of world's top research and development investors using patents and trademarks as proxy indicators. Moreover, in "OECD Science, Technology and Industry Scoreboard 2015" [7], apart from defining intellectual property indicators, scientific publication statistics are used to monitor developments in science, technology, innovation and industry in OECD and other leading economies.

III. Patents in mHealth

Intellectual property statistics were utilized in this work as proxy indicator of the innovation outputs in the domain of mHealth for patient monitoring. A study was performed to provide quantitative measures for the indicators measuring innovation outputs based on patent statistics. The scope of the study was the European market and the observation period between 2006 and 2015 was evaluated. Since the European market was considered, only the patents filed at the European Patent Office (EPO) [9] were analyzed. Thus, the EPO's database was the main source of information for this study, which was as follows. First, the EPO's database was searched to retrieve all the European patents related to mHealth for patient monitoring. Then, the collected data was manually processed to remove the patents which matched the search but did not really belong to the topic of patient monitoring using mobile technologies. Finally, the processed data was analyzed to determine the trends in this type of innovation, the evolution of the number of patents over the years and the principal geographical location of the inventions.

A. Method

Retrieving from the EPO's database the European patents related to mHealth for patient monitoring for the period of time from 2006 to 2015 was performed using the web interface Espacenet Patent search [10]. The query to retrieve these patents is shown in Listing 1. The search was based on the classification symbols of the Cooperative Patent Classification (CPC) system [11], a hierarchical structure that organizes the patents. The CPC symbols related to remote patient monitoring are *A61B 5/0002 - Remote monitoring of patients using telemetry, e.g. transmission of vital signals via a communication network* and *G06F 19/3418 - Telemedicine, e.g. remote diagnosis, remote control of instruments or remote monitoring of patient carried devices*. Therefore, the Cooperative Patent Classification field was stated to be equal to *"A61B 5/0002 or G06F 19/3418"*. Moreover, the search also combined keywords to ensure that the patient monitoring was performed using mobile technologies. Precisely, the query included in the search the words *"mobile"* or *"portable"* as keywords which had to be part of the title or the abstract of the patent. Furthermore, in order to restrict the search, only European patents were selected; thus, using the *"EP"* selector in the Application Number field. Finally, the range of the patent publication, from 2006 to 2015, was indicated in the Publication date field as the string *"2006-2015"*.

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mobile or portable in the title or abstract
AND EP as the application number
AND 2006-2015 as the publication date
AND A61B5/0002 or G06F19/3418 as the Cooperative Patent Classification
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Listing 1. Query to retrieve the European patents related to mHealth for patient monitoring for the period of time from 2006 to 2015.

The query generated a result set of 150 patents about mHealth for patient monitoring which were registered in Europe from the year 2006 to the year 2015 (see Figure 1). Even if the search tried to be as restrictive as possible, the set of results contained patents which did not describe inventions for the monitoring of patient using mobile technologies. Therefore, the set of patents which matched the query needed to be processed in order to eliminate the non-relevant ones.

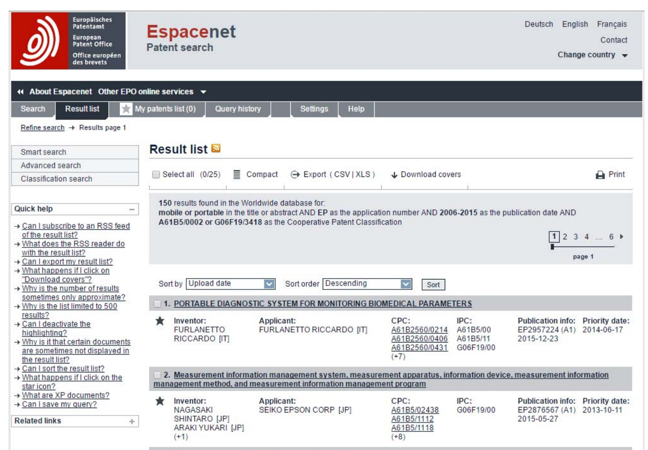

Fig. 1. Matching results from the Espacenet search.

The collected data about the 150 inventions possibly related to mHealth for patient monitoring registered as European patents between 2006 and 2015 were manually classified into eight categories. The first category "mHealth for patient monitoring" included the patents which described inventions for the monitoring of a patient using mobile technologies. The second category "diagnostic systems or medical devices" included wearable or portable medical devices which supported diagnosis but which were not connected to a mobile phone. The third category "display or representation of health data" was formed of solutions capable of displaying or representing the health data but which did not monitor the patient. The fourth category "communication of medical devices" contained solutions for the communication with medical devices in the case it was not established through the mobile phone. The fifth category "control or monitor of medical devices" was formed of solutions to control the parameters of medical devices or monitor their status. This category also included the remote configuration of such devices and actuators like an insulin pump. The sixth category "mobile applications in the health domain" consisted of methods for the development of applications which used medical information but did not monitor it. The seventh category "other health-related platforms or systems" contained other platforms or systems related to health but not mobile, for example a cloud-based clinical platform. Finally, the eighth category "NO mHealth" included any other solution not related to mHealth, for example robots for telemedicine. Figure 2 shows the number of patents classified into each one of these eight categories.

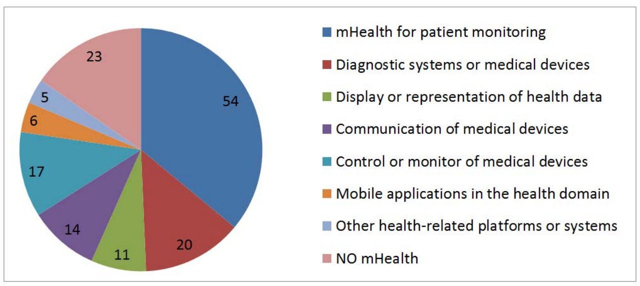

Fig. 2. Classification of the 150 inventions possibly related to mHealth for patient monitoring registered as European patents between 2006 and 2015.

The 54 patents classified into the category "mHealth for patient monitoring" were further analyzed to determine the trends in this type of innovation, the evolution of the number of patents over the years and the principal geographical location of the inventions.

B. Results

The resulting 54 patents related to the topic mHealth for patient monitoring and registered to the EPO between the year 2006 and 2015 were classified into three different categories (see Figure 3). The first category included the 14 patents which described mobile devices capable of monitoring the patients biosignals, biomechanic data or other health data. The second category was composed of the 30 patents which describe mobile monitoring devices connected to a remote server or back-end platform which enabled the processing of the collected data. Finally, the third category included the 10 patents which described some methods for the monitoring of patients in mobile devices, this mainly included mobile applications designed for remote patient monitoring.

A trend in mHealth for patient monitoring was observed due to the highest number of solutions which measured the glucose level (6) or the ECG or heart rate (5). Furthermore, 12 of the solutions proposed a method for signaling alerts whenever the monitored data reached certain conditions.

The evolution of the number of patents about mHealth for patient monitoring registered in the EPO between the

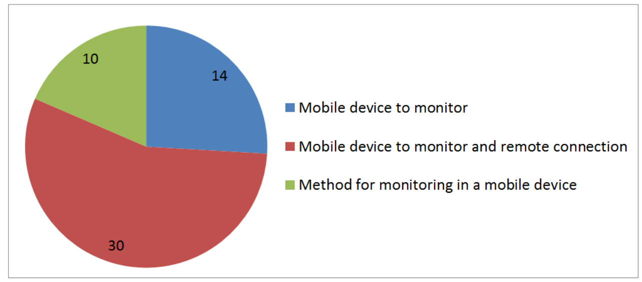

Fig. 3. Classification of the 54 inventions on mHealth for patient monitoring registered as European patents between 2006 and 2015.

years 2006 and 2015 is shown in Figure 4. Not only the absolute number of patents in mHealth is calculated but also the percentage these represent over the total number of patents registered at the EPO in the field of information technology and medical technology. The number of European patent applications filed with the EPO are obtained from the official EPO annual report and statistics, which are based on extracts from the EPO's monitoring database (EPASYS) [12]. The total considered patents are the ones classified by the EPO into the fields of technology "information technology" and "medical technology", as defined in the IPC-Technology Conordance Table [13]. One could not observe a clear trend on the number of patents about mHealth for patient monitoring registered between 2006 and 2015. The number of patents peaked in 2007, 2014 and 2015, and hit a low in 2010.

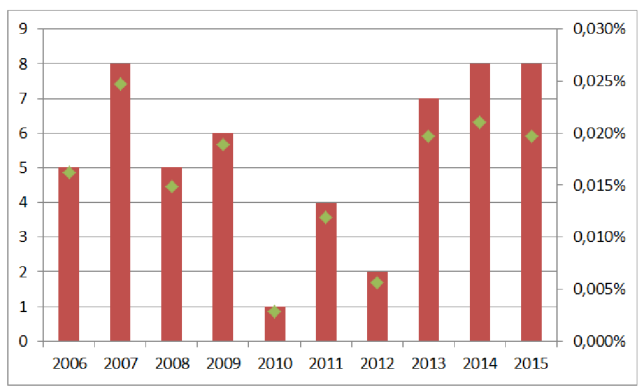

Fig. 4. Evolution over the years of the number of patents about mHealth for patient monitoring registered at the EPO. The bar according to the left axis indicates the absolute number of these patents registered at the EPO. The marker according to the right axis shows the percentage these patents represent over the total number of patents registered at the EPO in the field of information technology and medical technology.

The geographical location of the inventions was analyzed in terms of the applicant's country for each of the patents. Figure 5 shows the number of patents per each country. It can be observed that there were more patents registered by applicants of outside Europe than from inside, namely 35 versus 19. In Europe the most inventive countries are Italy and Germany with 5 patents each.

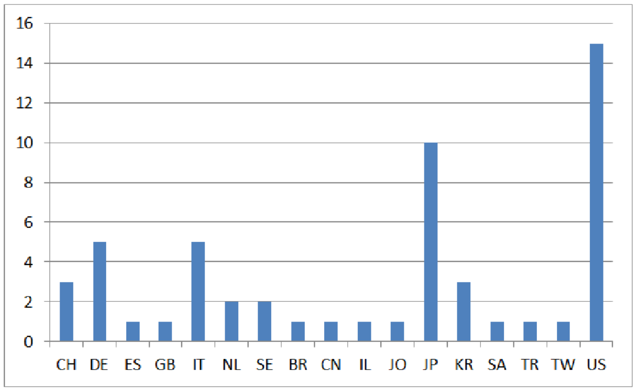

Fig. 5. Distribution of the number of European patents about mHealth for patient monitoring per applicant's country.

IV. SCIENTIFIC PUBLICATIONS IN MHEALTH

Scientific publication statistics are utilized in this work as proxy indicator of the innovation outputs in the domain of mHealth for patient monitoring. A study was performed to provide quantitative measures for the indicators measuring innovation outputs based on scientific publications. The scope of the study was the European market and the observation period between 2006 and 2015 was evaluated. The Elsevier's Scopus database [14] was utilized as the main source of information for this study because of its large amount of peer-reviewed literature. The study to analyze the scientific publications was performed as follows. First, the Scopus database was searched to retrieve all the publications related to mHealth. Then, the collected data was manually processed to obtain the publications about patient monitoring using mHealth. Finally, the processed data was analyzed to determine the trends in research, the evolution of the number of scientific publications over the years, and the principal geographical location of the scientific production.

A. Method

Retrieving from the Scopus database the publications related to mHealth for patient monitoring for the period of time from 2006 to 2015 and published by authors affiliated to European institutions implied the creation of the query presented in Listing 2. The query retrieved all the publications which had in their title, abstract or keywords the term “mhealth” or the term “mobile health” excluding the phrase “mobile health unit”. The search results were restricted to remove all the publications about mobile health units, i.e., medicalized vehicles, which matched the phrase “mobile health” but in fact did not relate to mHealth. The year of the publication was restricted to the observation period from 2006 to 2015. The country was limited to include the 28 member states of the European Union plus Switzerland and Norway, so that the search results were restricted to publications of authors affiliated to European institutions. Furthermore, the document type was restricted to article and book chapter. Conference papers were not considered since their impact is more reduced than journal articles, and in most of the cases they present preliminary results which researchers tend to extend and submit to journals. Thus, considering the articles published in journals should have included most of the leading research work published in conferences.

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TITLE-ABS-KEY(
( ‘‘mobile health’’ AND NOT ‘‘mobile health unit’’ ) OR mhealth
)
AND PUBYEAR > 2005
AND PUBYEAR < 2016
AND (
LIMIT-TO(DOCTYPE,‘‘ar’’ )
OR LIMIT-TO(DOCTYPE,‘‘ch’’ )
)
AND (
LIMIT-TO(AFFILCOUNTRY,‘‘United Kingdom’’ )
OR LIMIT-TO(AFFILCOUNTRY,‘‘Spain’’ )
OR LIMIT-TO(AFFILCOUNTRY,‘‘Italy’’ )
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OR LIMIT-TO(AFFILCOUNTRY,‘‘Slovenia’’ )
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Listing 2. Query to retrieve the publications related to mHealth for patient monitoring for the period of time from 2006 to 2015 and published by authors affiliated to European institutions.

The query generated a result set of 366 journal articles and book chapters about mHealth published between 2006 and 2015 by authors affiliated to European institutions (see Figure 6).

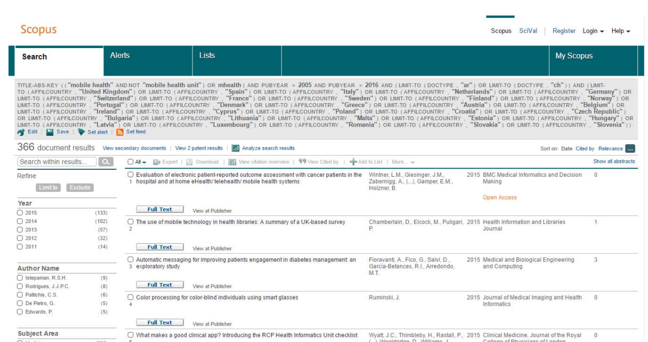

Fig. 6. Matching results from the Scopus search.

The collected data about the mHealth articles and books chapters published between 2006 and 2015 by authors affiliated to European institutions was further processed to eliminate the publications which were not related to mHealth for patient monitoring. Therefore, the 366 publications were manually classified into one of the fourteen categories of mHealth services defined by the WHO in the 2009 Global eHealth survey [1] or into another five self-defined categories. These new five categories were defined since the fourteen categories of mHealth services were not enough to classify all the publications. For example, a publication could not focus on a particular mHealth service but provide a general overview about mHealth, this was the case of some state of the art reviews and studies about the adoption or trends in mHealth. The publications belonging to these two groups were identified and classified into the two corresponding categories: "state of the art on mHealth" and "adoption and trends on mHealth". Furthermore, some publications made reference to mHealth but they described technologies that could be applied to any other field as well. Therefore, these publications were classified as "technology used in mHealth". Similarly, some publications defined security and safety solutions that could be applied to mHealth. In this case, the publications were classified as "security and safety in mHealth". Finally, some publications matching the Scopus search were not related at all to the topic of mHealth. This is the case of some publications about robots or wearable cameras which did not make use of mobile phones to provide the health service. In case the publication was related to more than one mHealth service, the most prominent one was selected for its classification. However, in any case the publication belonged to the topic "patient monitoring", this category was prioritized. Figure 7 shows the number of publications classified into each one of the nineteen categories.

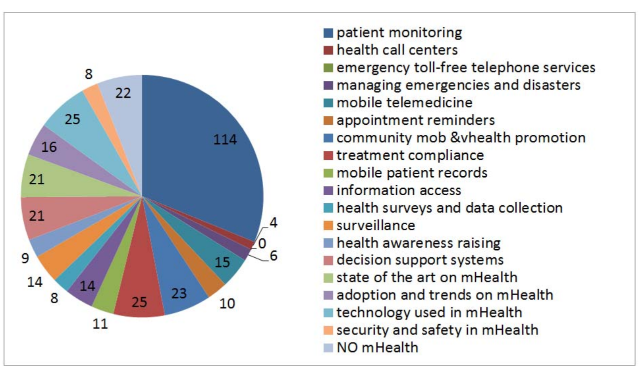

Fig. 7. Classification of the 366 journal articles and book chapters about mHealth published between 2006 and 2015 by authors affiliated to European institutions.

The 114 publications classified into the category "patient monitoring" were further analyzed to determine the trends in research, the evolution of the number of scientific publications over the years, and the principal geographical location of this scientific production.

B. Results

The resulting 114 publications related to the topic mHealth for patient monitoring in which participated European researchers and which where published between the year 2006 and 2015 were classified into four different categories (see Figure 8). The first category included the 93 publications which described mHealth solutions for patient monitoring. For example, mobile applications for sensor-based or self-monitoring of patients, frameworks to support the creation of these applications, and body sensor networks for measuring biosignals. The second category was composed of the ten publications studying the market on patient monitoring. The third category included the six publications which described some technology that supported mHealth solutions for patient monitoring, such as mechanisms improving the communication among the sensors capturing the patient information and the mobile device. Finally, the fourth category was composed of the five publications about security and safety, like one about privacy in the biosignals transmission.

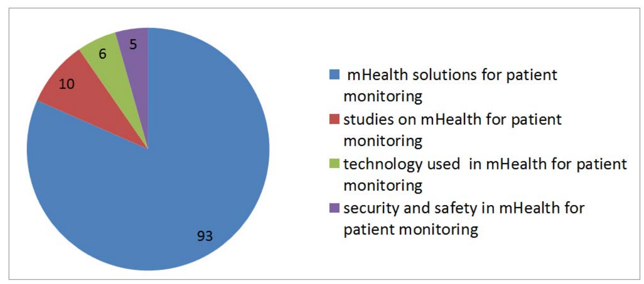

Fig. 8. Classification of the 114 journal articles and book chapters about mHealth for patient monitoring published between 2006 and 2015 by authors affiliated to European institutions.

The main trend in mHealth for patient monitoring was observed to be the creation of novel mobile phone applications connecting sensors for monitoring some physiological, physical or mental characteristics of the person. In fact, in 17 publications ECG or heart rate were monitored, in 12 the level of glucose was recorded to monitor diabetes and in 11 movement was sensed in order to detect activities or falls.

The evolution of the number of publications about mHealth for patient monitoring from 2006 to 2015 is shown in Figure 9. One could observe the increasing trend on the number of publications. In fact, in 2012 there was a boost on this topic and in two years the number of publications doubled reaching the value of 33 in year 2014.

The geographical location of the scientific production was analyzed in terms of the location of the institution to which the first author was affiliated and in terms of the collaboration in joined publications between authors affiliated to institutions of different countries. Figure 10 shows the distribution of the number of publications per each country where was located the institution to which the publication first author was affiliated. A total of 104 publications where published by a first author affiliated to an institution located in one

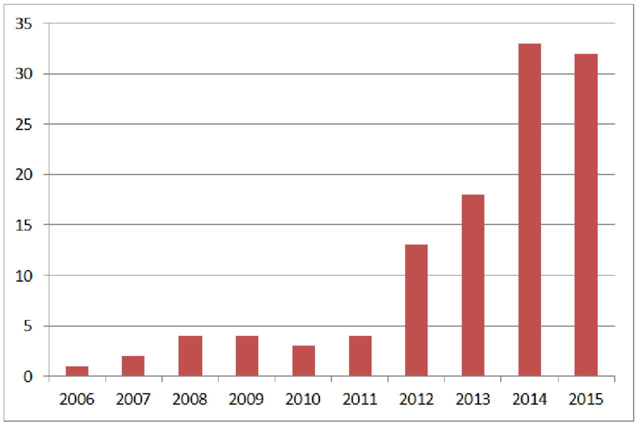

Fig. 9. Evolution over the years of the number of publications about mHealth for patient monitoring published by authors affiliated to European institutions.

of the 19 European countries. Conversely, in 10 publications the first author was not affiliated to an institution located in Europe but collaborated with other researchers working in European institutions. One could observe that Italy (with 20 publications), United Kingdom (18) and Spain (17) were the main countries in scientific production considering the location of the institution to which the first author was affiliated.

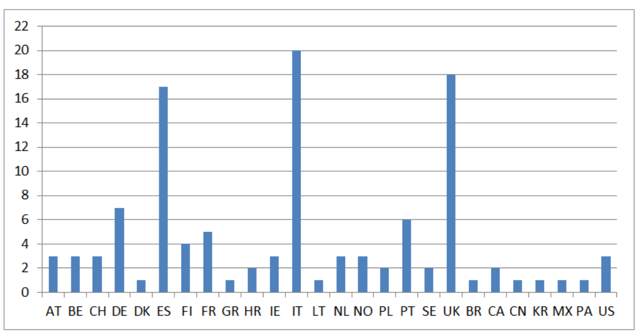

Fig. 10. Distribution of the number of publications per each country where was located the institution to which the publication first author was affiliated.

From the 114 publications, in 40 of them participated researchers affiliated to institutions from more than one country. In fact, in 31 publications collaborated institutions from two countries, in 7 from three countries, in one of them from four countries, and in another one from five countries. International collaborations between researchers of European institutions from different countries were established in 15 publications. The count per each country of publications in which participated authors affiliated to institutions in that country in collaboration with authors of institutions located in other European countries is presented in Figure 11. International collaborations between researchers working in European institutions and other researchers affiliated to institutions outside Europe were established in 25 publications. The count per each country of publications in which participated authors affiliated to institutions in that country in collaboration with authors of institutions located in other non-European countries is presented in Figure 12. Spain is the country with the most international collaborations both at European and non-European level. Researchers affiliated to institutions located in Spain jointly published articles with researchers of non-European institutions, mainly located in South Korea, Mexico, Panama and the United States.

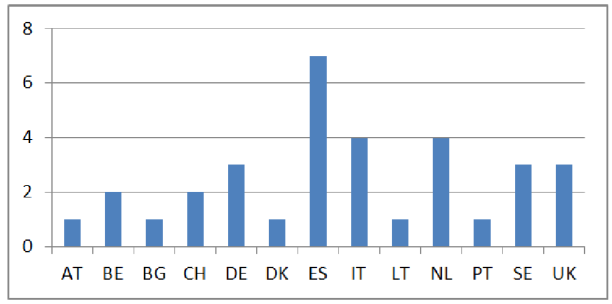

Fig. 11. Count per each country of publications in which participated authors affiliated to institutions in that country in collaboration with authors of institutions located in other European countries.

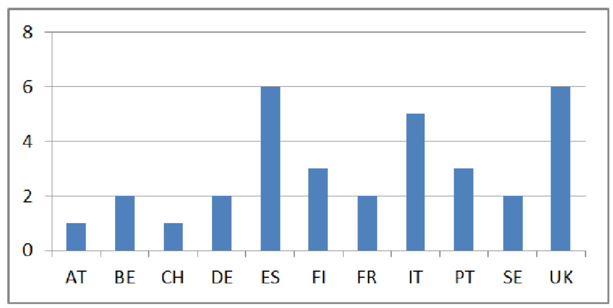

Fig. 12. Count per each country of publications in which participated authors affiliated to institutions in that country in collaboration with authors of institutions located in other non-European countries.

V. Discussion

The two different studies provided an overview of the outputs of innovation in the domain of mHealth for patient monitoring at European level for the period of time between 2006 and 2015. Patents statistics and scientific publications statistics proved to be a good proxy indicator to measure the outputs of innovation. Individual results of the studies were described and commented in the corresponding sections. Therefore, here only the comparison of the results is discussed.

Contrasting the methodology applied in the two studies, it could be observed that even if the overall procedure was the same, this means collecting the information, processing it and analyzing it, depending on the characteristics of the search results for the data collection different approaches were followed. In the case of the search on the patents' database, the search was for the key concept "patient monitoring" and then the results were manually restricted to the mobile domain. In the case of publications, the search was more generic matching the term “mHealth” and then the publications about patient monitoring were manually extracted.

Comparing the results of the study about the patents and the study about the publications, one realized that even if European institutions published a lot on the topic of mHealth for patient monitoring, they did not protect their inventions. In fact, more than half of the patents registered in Europe were applied from the United States or Asia. Furthermore, the European countries that published the most were Italy (20), United Kingdom (18) and Spain (17), and from them only Italy applied for a considerable number of patents (5). Conversely, Germany, which also applied for 5 patents, published 7 journals articles.

VI. Conclusion

This work explored the role and trends of innovation in the area of mHealth for patient monitoring. In order to determine the performance of innovation activities, it was required to measure innovation in a comprehensive manner. Proxy indicators, like intellectual property statistics and scientific publication statistics, were utilized in this work to measure the outputs of innovation. Patent statistics proved to be a good indicator of the inventive output in terms of technological innovations. Statistics on scientific publications provided a good measure of scientific production and enabled the identification of the trends in research and innovation activities.

The outputs of innovation in the domain of mHealth for patient monitoring for the European market during the years 2006 to 2015 were successfully quantified in this work in terms of patents and scientific publications. These innovation indicators were calculated in two different studies which explored the patent data collected from the EPO’s database and the publication data collected from the Elsevier’s Scopus database. These studies analyzed the trends of innovation, the evolution of innovation over the years and the principal geographical location of the innovation. It was observed that even if there was a lot of research in Europe about mHealth for patient monitoring, the vast majority of the enterprises did not protect their inventions. Moreover, a strong research collaboration in the area of mHealth for patient monitoring took place between researchers affiliated to institutions of different European countries and even with researchers working in Asian or American institutions. Finally, it was identified an increasing trend on the number of published articles about mHealth for patient monitoring. All these facts demonstrated the great interest that had arisen the field of mHealth and the huge involvement in innovation activities in the area of mHealth for patient monitoring.

The results of the studies on the outputs of innovation in mHealth could serve as guidance for companies in the health sector to firmly commit to innovate on mHealth or for governments to promote the innovation in this domain. In fact, it would be quite recommended to protect the intellectual property with more patents so that enterprises could benefit from the exploitation of these inventions. Moreover, it should be ensured that the research does not generate simply ideas and prototypes which are not applied to new products. Thus, institutions should make sure that the innovations make their journey to the market as novel products and services. This means that enterprises should see innovation as a keystone of their business strategy since it provides them a great competitive advantage. Furthermore, all the stakeholders involved in the provision of healthcare should consider the utilization of mobile health technologies in order to reduce costs and provide more personalized and high-quality health services.

This work provided an overview of the trends of innovation in the domain from mHealth for patient monitoring based on the outputs of innovation. In future work, other indicators for the outputs of innovation could also be evaluated, like for example the link between science and innovation. In order to have a more holistic view about innovation, this work could also be extended to measure and evaluate the inputs and impacts of innovation. This would involve performing some studies on the resources devoted to research and innovation, the turnover generated by the innovations, and the employment generated by the innovation activities.

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