Wearable technologies – future challenges for implementation in healthcare services

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The growing use of wearable technologies increases the ability to have more information from the patient including clinical, behavioural and self-monitored data. The availability and large amounts of data that did not exist before brings an opportunity to develop new tools with intelligent analyses and decision support tools for use in clinical practice. It also opens new possibilities for the patients by providing them with more information and decision support tools specially designed for them, and empowers them in managing their own health conditions, keeping their autonomy. These new developments drive a change in healthcare delivery models and the relationship between patients and healthcare providers. It raises challenges for the healthcare systems in how to implement these new technologies and the growing amount of information in clinical practice, integrate it into the clinical workflows of the various healthcare providers. The future challenge for healthcare will be how to use the developing knowledge in a way that will bring added value to healthcare professionals, healthcare organisations and patients without increasing the workload and cost of the healthcare services. For wearable technology developers, the challenge is to develop solutions that can be easily integrated and used by healthcare professionals considering the existing constraints.

1. Introduction: Over the past several decades, telemedicine systems have demonstrated the capacity to improve access to all levels (primary, secondary and tertiary) of healthcare for a wide range of conditions, including chronic diseases and psychiatric disorders, as well as services such as rehabilitation. It also promotes patient-centred care at lower cost delivered in the patient's natural environments, enhances efficiency in clinical decision-making, increases effectiveness of chronic disease management and promotes individual adoption of healthy lifestyles and self-care [1, 2]. Presently, virtual visits and online consultation, prescription and treatment are embedded in healthcare services. There is a growing use of sensors for remote monitoring of clinical parameters and lifestyle applications. Sensors are commonly used for detecting and transmitting/storing vital signs or physiological data, and for measuring and detecting levels of activity. Availability of technologies at lower costs and access to high-capacity telecommunication networks, as well as increasing level of computer literacy in the population, advanced the development of wearable technologies and tele-homecare. The field of health smart home that enables the remote control of automated devices specifically designed for remote healthcare and combined with wearable devices further developed the possibilities and knowledge about the individual's behaviour and condition and increased the provided services. Rather than focusing solely on the patient's health concerns, this approach considers the patient as a human being in a social and geographic environment. This patient-centric approach to telemedicine takes advantage of developments in both tele-care and smart homes. Another advantage is that it can be linked to services that are not directly related to health such as social interactions, security and safety, and are highly relevant to elderly people with age-related problems and not a specific disease monitored by a specific medical device. The development of systems linking smart homes, non-clinical data and healthcare opened a new dimension to healthcare monitoring, detecting analysing and alerting. This includes the unobtrusive monitoring at home by observing and assessing vital signs to provide valuable information with respect to the health condition of the ones monitored, without requiring extra care or effort from them. For example, unobtrusive physiological monitoring using visual information from skin reflection for measurements of vital signs, combined with data obtained by a wrist watch device, provide additional knowledge that enables more efficient decision-making. Thus the linkage between wearable technologies and environmental ones further advance the development of analytical tools. To develop tools that will address the needs of the care provider; monitoring, analysing, diagnostics and alerting; can also be implemented in existing workflows of healthcare, and also integrated into existing systems, a process that will require research of care models, development of integrated care methodologies that are cross-organisational and cross-cultural. On the technological level, one of the major challenges is the development of analytical tools and decision support tools that will use heterogeneous data for the understanding of behaviour and risk detection and clinical condition evaluation. Data collecting, transferring, saving and sharing will require not only development of technological solutions for treatment of big data and data channelling, but also development of legal infrastructure that will enable different organisations to share data and share the care responsibilities for the patient.

2. Wearable technologies: Wearable technologies provide data monitoring of clinical data and behavioural data such as activity levels, type of activities and social activity/interactions. The development of the wearable technologies that monitor different types of data and can combine this data to yield additional information about a wide range of parameters and activities, including behavioural, mental and clinical, opens new opportunities for care providers but also requires the integration of care models.

2.1. Clinical data: Clinical data can be obtained from a number of off-the-shelf monitors that can measure blood-pressure (BP), heart-rate and oxygen saturation (O_2), glucose levels, body weight and vital signs exist that can wirelessly transmit their readings to a smartphone or PC using Bluetooth technology or similar. Many applications were developed for data capturing and presentation both for the patient and the care provider. It is commonly used and the main barrier for the wide implementation in healthcare is the cost of the wearable transmitting devices and the cost/lack of communication infrastructure for transmitting the data especially for the older population, which is the primary target for these services. Tools and applications that further analyse the data and alert for abnormal conditions are developed at the level of the sensors that creates alerts and/or at the level of the healthcare provider systems after the data are transmitted to assist the treatment process. These types of data and services are designed to be integrated into the clinical workflows of healthcare professionals [3]. The monitored data are focused on

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clinical parameters related to the patient's clinical condition (diabetes, CHF, COPD etc.) and is usually treated in a reactive way in which the healthcare provider responds to abnormal levels and alerts. In some cases, the monitored data is used for proactive treatment combined with treatment plans such as the Maccabi healthcare services multidisciplinary centre approach that also involves the patient in the care process [2, 4]. The monitoring and use of data is limited to specific patient populations defined by a healthcare provider and used within special programmes of care following defined clinical protocols. The data can be further analysed for risk assessment of stratification for timely intervention. In these cases, data entered by the patient regarding his condition is pre-defined by the care provider and used as part of the treatment and for further assessment of the patient's condition. However, there are other cases in which data collected by an individual using a wearable device and analysed by a commercial online application on the mobile device that is not connected to healthcare providers. Whether the individual is healthy or has some chronic conditions that do not meet the criteria of the special care programs provided by healthcare organisations, this is not treated by physicians as clinical data in the EHR as part of the clinical process. In some cases, the patient may upload it to his personal health record (PHR) and discuss it with the doctor but the data will not be integrated into the EHR and the physicians are not liable for the information and/or risks detected this way. Furthermore, this data is not used by the healthcare system for population-based analyses and research. Therefore this information is 'lost' as a basis for analyses and decision support tools. The challenge of healthcare systems will be to find ways to use this data for early detection and prevention for healthy patients using their own devices providing additional information to that which exists in the EHR. The challenge for the wearable technologies industry is to provide the healthcare system with user-friendly solutions that are validated and can be easily integrated into the existing systems considering privacy and security requirements.

2.2. Behavioural data: Behavioural data is collected from wearable devices and includes information about an individual's activity, type of activity, such as intensity of activity indicating running, walking or climbing stairs and patterns of activity (daily activity patterns). The activity data can be used for early detection and better understanding of patient conditions such as motor problems in Parkinson disease (FOG, dyskinesia etc.), patients with bipolar disorder, posture and gait problems in the elderly population that can be used to assess risk for falls and activity of daily living assessment using related indicators [5, 6]. Another use for the activity data is in the field of wellness behaviour for healthy people. Many off-the-shelf devices that exist today, and even sensors embedded in mobile phones, can provide valuable information regarding the individual's behaviour and, when linked to GPS and self- reporting tools on mobile, they can help detect and alert for early detection of some risks. However, this data remains in the hands of the user and does not reach any responder. In an elderly population, combined with an emergency button, it is commonly used for fall detection and for location identification of the person in case of dementia. These services are linked to emergency centres; however, the information is not linked to healthcare and the care provider does not receive an indication about the actual condition of the patient – although this information exists. Using this information can help the physician better understand the patient's clinical condition. Technologies can also provide input regarding the actual behaviour (compared with self-reported) of the user and be compared with the treatment for assessment of adherence and compliance to therapy. Mental condition assessment [3, 7–9], and cognitive condition can also be assessed using these technologies, leading to early detection and timely intervention. For example, if the patient tends to fall, is there a cognitive decline or at what stage of dementia is the patient and decisions are made about an adequate treatment. New technologies developed in recent years can be implemented as part of the overall solution. For example, psychological stress and poor sleep quality of a person may serve as indicators for predicting the onset of mental health problems, in particular depression and/or anxiety that are the most common medical conditions, affecting 39% of patients of all ages [10]. It was also found that slow gait, cognitive complaints predict cognitive decline. Motoric cognitive risk syndrome is common in older adults, and is a strong and early risk factor for cognitive decline. This clinical approach can be easily applied to identify high-risk seniors in a wide variety of settings [11]. Using these tools for the treatment of large populations at risk such as elderly populations can improve the quality of care and the save cost of treatment at later stages. Presently, there are no supporting tools that can help the healthcare professional implement it into their workflow such as risk analyses and care pathways using this information. These technologies are at early stages of adoption, mainly in dedicated programmes and at pilot level and it is still unclear how it will be implemented in the care process.

3. Analyses and decision support tools: Analyses and decision support tools are widely used in healthcare at all levels; clinical, administrative and management. For doctors, there are many tools implemented in the EHR or in systems that are integrated to the EHR that assist the physician in his work; analyses of the patient's information, statistics, data trends over time, alerts and reminders, rule-based decision support systems (DSSs) as well as embedded guidelines. In some organisations such as Maccabi Healthcare Services there are tools that enable the organisation to set clinical goals for the doctors. For example, for flu vaccination, target for cholesterol levels in cardiac patients, control of hypertension in diabetic patients, screening levels for BP or colon and breast cancer screening and so on [12–14]. For other healthcare professionals such as nurses there are tools that assist proactive approaches and health promotion in the community.

Implementation of these tools improved clinical outcomes over the years and are well accepted by both doctors and organisations. The level of implementation of these tools in healthcare changes in different countries and organisations; however, they are well accepted. The long-time experience and remarkable outcomes obtained by using these tools created readiness of the market for wearable technology tools to be implemented in healthcare. The challenge of treatment of the elderly population and to provide care for a large population with complex needs creates a growing need for analytical tools that will help the healthcare professionals provide qualitative care for large populations. Wearable technologies will become the origin of large amounts of this valuable data. With the development of wearable devices that are monitoring heterogeneous data, there is a vast development of analytical tools [3, 12]. Since there is a readiness of the market to adopt these technologies, it is important to provide analysis tools, DSS and additional tools that assist the care provider in the treatment, as easy to use tools that are compatible with the existing systems and address the needs of the healthcare professional. The challenge is to develop tools that will monitor, analyse, diagnose and alert but that can also be implemented in existing workflows and systems. Most healthcare organisations have their own systems and implementation requires adaptivity of the developed tools. Furthermore, in each organisation there is a different set of databases and populations that may change the validity and sensitivity of the analytical tools. Therefore the commercial product must be open to different systems that exist in healthcare. Developers will have to work with the end user to better understand how they work and what type of tools can add value to their work to enhance adoption.

Another aspect of DSS in wearable technologies is related to self-management of the patient. A comprehensive solution that will enable the patient to become a co-manager of their health and disease, enjoy preventive medicine and the making of decisions

becomes mandatory. Today, there are some tools that are provided by the healthcare providers to their members such as alerts and reminders for follow up and tests, risk assessment tools online personalised to their clinical condition, recommendations and educational materials for their clinical conditions, PHR in which a patient can upload their data; self-monitoring of BP and weight as well as consultations in private clinics. Lately, there are even some coaching tools for behavioural change, mainly in health promotion and wellness. These tools exist on the Internet portals and on mobile phone applications and in some cases are connected to data coming from wearable devices. Healthcare organisations do not implement DSS and tools for self-management for patients with complex conditions that do not involve care and decision-making by the healthcare professionals since it raises issues regarding liability and regulation. Development of such solutions will require further research about the emotional, social and clinical needs of the different population, the needs of the supporting networks such as family, friends and communities, and the developments of new models of care that use these advanced technologies in a meaningful way for the care and support of the patient. There is a need to define which DSS can be provided to the patient and informal care provider and this will require education of the population, both patients and healthcare providers, on how to use these tools and create an effective co-management. It will build new relationships between clients and healthcare professionals. This is a process that will require research of care models, development of integrated care methodologies that are cross-organisational and cross cultural.

On the technological level, one of the major challenges is the development of analytical tools and decision support tools that will use heterogeneous data for the understanding of behaviour and risk detection and clinical condition evaluation. The tools have to be validated on a large scale and provided with high-quality validated results before they can be implemented in healthcare systems and become part of the care pathway. With the development of wearable technology systems that monitor heterogeneous data, the need for analytical tools will grow. This research will have to combine clinical and non-clinical data for better understanding of the process of alerting and treating patients in the future.

4. Barriers of implementation: Barriers of implementation of wearable technologies in daily use in healthcare systems originate from the structure and care delivery models of the healthcare system, and from immaturity of the solutions existing today.

The healthcare system today is dispersed and the care delivery model does not allow sharing of information and care. The patient receives care at different points and each care provider (e.g. hospital, GP) has partial data. Therefore the tools used by the healthcare system are focused on specific sets of data and are directed to specific goals according to the user (GP, specialist, nurse etc.).

Wearable technologies aim to provide additional information that integrates data from different sources, complement the clinical data that exists on the EHR and generate new knowledge. This knowledge can be used by different care providers in different points of care. Implementing wearable technologies will require change in the delivery model, responsibility and data sharing between doctors, other care providers and even other organisations including informal carers such as families. For example, even when a wearable sensor system provides information about motor and non-motor aspects of Parkinson's disease patients, it can presently only be implemented in a hospital and provide the information to the neurologist. The patient who is treated in the community by his GP and by nurses, physiotherapists and sometimes social care services cannot be treated based on the information sent and analysed by the wearable sensor since the data cannot be transferred to the other care providers connected to different systems. Recently, there has been a remarkable upsurge in the adoption of PHR systems. PHR combines data from the EHR and data from the patient and therefore includes knowledge, which helps patients to become active participants in their own care. This can also provide a solution for data sharing when coming from the wearable devices and the various care providers, however, while EHR systems function to serve the information needs of healthcare professionals, PHR includes health information managed by the individual. This can be contrasted with the clinician's record of patient encounter-related information. The reliability of patient-entered data depends on the nature of the information per se, the patient's general and health literacy, and the specific motivations for recording the data. It also involves legal concerns on the part of providers and the privacy concerns of individuals. For example, courts might apply negligence standards in cases where practitioners rely on inaccurate patient-entered PHR information to make suboptimal decisions about care. The workflow models for both providers and patients are poorly understood [15]. The same issue exists with using data coming from wearable devices that provide behavioural and clinical data regardless of the tool for data sharing. Using heterogeneous data, coming from different sources relying on patient and informal carers is considered 'not approved/validated' by the healthcare system and therefore considered 'non-reliable data'. Working with this data can bring to problems regarding liability and responsibility as well as problems of data security and privacy.

Healthcare providers begin to change the mode of delivery of care from a fragmented delivery focusing on disease-specific care to new models with more coordinated care that will improve care delivery and care quality. Intervention modalities of care in the future will consider the individual's preferences and needs, and will implement member-focused programmes. Integrated care models are slowly becoming implemented and will combine healthcare and social care. This will drive adoption of wearable solutions that can provide data to all care providers such as behavioural, functional and mental information and will include families and friends in the loop.

Another barrier of adoption is the time required from the physician to use this data compared with the added value provided by it. Today, the existing tools are not integrated into the systems, this means that the system is accessed separately by the doctor. These data and analyses are usually presented in a different way on different screens on the physician's interface. This requires additional time, education and training to work with the system, which increases the workload and cost for organisations. The incentives to do so are low since the tools are not validated and the care pathways using this information are not defined yet. There are no supporting tools such as risk analyses and care pathways using this information. These technologies are at early stages of adoption, mainly in dedicated programmes and at pilot level and it is still unclear how it will be implemented in the care process. Therefore, the information should be analysed and validated, ensuring an added value for the treatment is well presented. The tools should be easy to use by the healthcare professional and that can be implemented as part of the best practice and workflow to enhance adoption by the care providers [16].

This becomes more problematic when related to the treatment of healthy population or patients with some chronic condition at early stages. Despite the increase in health plans for health promotion, early detection and prevention, still, these patients do not cost much to the healthcare system. There is a growing understanding that treating this population will produce cost saving in the long term as healthcare organisations slowly move towards these health programmes, however, the need for use of data that can be provided by wearable technologies and the ROI using these technologies is still unclear. The business models developed for marketing these solutions are unclear and combine B2B models with B2C models. To implement these solutions, there is a need for communication infrastructure that does not exist today and it is unclear who will pay for it. The cost of the technology is also a barrier and healthcare organisations cannot pay for it. This is the reason it is provided only to small populations with specific needs.

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Another barrier for healthcare organisations is the amount of data. Wearable technologies generate large amounts of data. These data have to be treated by the healthcare system considering all constraints of security and privacy.

Although standardisation in the healthcare domain is not well defined and many standards are used in different systems, some countries, such as Denmark, started to adopt standardisation policies. The development of wearable devices should consider standardisation, privacy and security issues, and interoperability.

5. Challenges: There are challenges for both the healthcare system and the wearable technologies industry in implementing wearable technologies in healthcare. For the healthcare system, the main challenge is to enable the use of these technologies by changing the model of care and sharing information. Implementation of these technologies requires the collaboration of the healthcare professionals and patients, not just in adoption, but also in the process of development and implementation in best practice and care pathways.

Advancing the research and development of systems that will bring additional information and knowledge to that which already exists and find the best way to use it in practice will advance care quality. It will include physician engagement, accepting the patient as a partner in the care process by educating him, providing him with tools, data and information. This will open the way for sharing information from the patient and other sources, capturing and analysing patient data from dispersed systems. This also requires changes in regulation regarding use of data, privacy and security.

For wearable technologies, the challenge is to develop supporting systems that will enhance adoption, consider constraints of standardisation, privacy and security, and the existing models of care. The developer should consider the healthcare professionals' workloads and workflows and adapt the solutions to the system. To implement the wearable technologies, the industry should develop more low-cost solutions and new business models that will enable healthcare organisations to adopt the solution at large scale.

6. Conclusion: Wearable technologies open new opportunities by bringing new information and knowledge for healthcare providers, clinical practices and other care organisations, as well as to patients. The ability to collect continuous data from different origins, clinical and behavioural, will enable the development of analytical tools for a better understanding of disease development and progression, early detection and intervention. This knowledge and these tools will change the clinical practice and patient involvement in self care and decision making. The amount of collected data will increase dramatically and, since the collected data origin is heterogeneous, coming from monitoring of clinical parameters, self-monitoring and behavioural data, there will be a need to find ways to treat and use this data, implement the knowledge into the best practice and to use it as part of the existing workflow, sharing information with other organisations, the patient and family and to develop methodologies for interactive treatment. These changes are at early stages and will develop in the coming years, driving two processes: a change in a care model moving towards integrated care and co-management with the patient and the development of new tools that will bring new knowledge to clinical practice. These processes will also drive change in the regulation of data privacy and data sharing and on the technological aspect, enhance implementation of more interoperable and standardised tools that can be easily integrated in care systems. In parallel to these long-term processes, there is a short-term challenge of developing more mature products that address the care providers' needs and can complement the existing tools used by the healthcare professionals today. The real challenge of all involved parties; healthcare, policy makers and the industry, is to work together to find ways to implement these solutions for the benefit of all populations at low cost and high quality that will improve the care delivery models and clinical practice.

7 References

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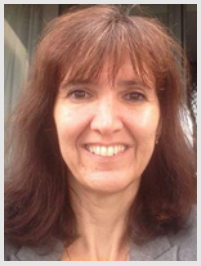

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