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Wishes For Wearables From Patients With Migraine

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WISHES FOR WEARABLES FROM PATIENTS WITH MIGRAINE

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Abstract

Migraine is a long-term failure mode, including a risk of disease-related deficits, that leads to social exclusion. The study was conducted among members of the Finnish Migraine Association and was aimed at identifying migraine patients with pre-symptoms and whether they would be willing to use wearable sensors to detect pre-symptoms. The survey received responses from 565 persons, 90% of whom were willing to use wearable sensors to measure pre-symptoms and support treatment. Moreover, the study revealed that 87.8% of migraine patients identified migraine's early symptoms, the most common of which are tiredness, slow thinking, difficulty finding words and visual disturbances. Most of the respondents wanted the device placed on their wrist as a watch, wristband or skin patch.

Keywords: Migraine; pre-symptoms; wearable sensors; chronic diseases; health promotion

1 Introduction

The purpose of the study was to generate information about the potential wearable devices that patients with migraine would be willing to use and/or were interested in.

Migraine is a partly genetically determined and wide-ranging neurological disease. Studies have suggested that 10 to 15% of the global population suffer from migraines, constituting one of the main health burdens in many countries (Belam et al., 2005; Kaattari et al., 2015; Kallela, 2005). If a migraine patient needs health care 7–17 times in a single year, then that patient is classified as a heavy user of healthcare services. Medical studies show that heavy users burden health centres; therefore, identifying migraine patients and health problems throughout the development system of healthcare is important (Berg and Stovner, 2005; Kaattari et al., 2015).

Recent developments in information and communication technology (ICT) offer a promising path to support and relief for patients with severe migraines and neurological problems in general (e.g. Timpano et al., 2013). While Timpano et al., (2013) reported about the use of telemedicine, Oluwagbemi and Ughamadu (2016) proposed a mobile application as a functional solution for dealing with and managing hereditary diseases.

The research problem in question involved obtaining knowledge from patients suffering from migraines, particularly whether they were interested in using wearable sensors to manage their migraines, and especially to identify the early symptoms of their migraine attacks. The research problem was formulated as the following research question:

What kind of wearable sensors would patients with migraines use to manage their migraines and receive early warning of the pre-symptoms of their migraine attacks?

The research question was answered with the help of a questionnaire that included both quantitative and qualitative questions. Altogether, 565 patients answered the questionnaire with sufficient content to be analysed. The data were analysed with the help of SPSS 3.0 tools. The qualitative answers were read several times over and interpreted for the analysis.

The results of the study showed that patients with migraines were definitely willing to use wearable devices to ease their condition; moreover, the sensors yielded valuable knowledge that can be used to develop the system further in the future.

This paper presents relevant previous research related to the topic, and then describes the current study and its results.

2 Previous Research

A migraine is said to be a relatively severe form of headache (Berg and Stovner, 2005; Burstein and Woolf, 2000). Because of hormonal changes, women suffer from migraines far more than men. The peak of migraines is measured to be between 25 and 44 years of age (Kaattari et al., 2015; Pagán et al., 2015). Migraines also belong to a large group of hereditary diseases (Oluwagbemi et al., 2016).

Based on their 10-year-long study, Olesen et al., (1990) noted that migraines with an aura constitute 'classic migraines' and proposed a simple model for migraine attacks whereby aura symptoms are followed by a migraine headache after a time delay.

Migraines can be divided into four phases: pre-symptoms of migraine, aura, migraine attack and postdrome (see Figure 1). Studies have shown that migraine attacks are rapidly changing in shape, lasting between 4–72 hours. A migraine is considered chronic if a patient has 15 headache days over a three-month period (Burstein and Woolf, 2000; HIS, 2013). According to the World Health Organization, chronic diseases consume more than one-half of total healthcare expenditures (Lymberis and De Rossi, 2004).

Pre-symptoms of migraine can be detected a day before a migraine attack. Common pre-symptoms include fatigue, yawning, increased appetite, cravings for sweets, irritability and feeling cold. An aura or pre-symptoms usually last for 5–60 minutes and include light-sensitive eyes, smell sensitization, visual field defects, sound sensitivity and numbness of the face. There are two types of medicine for migraines: preventive medication taken daily and acute medication taken when pre-symptoms are detected. The power of migraine treatments depends on at which stage of the attack the medication is administered. The best response to acute medication occurs when the drug is taken prior to the headache phase (Burstein et al., 2004).

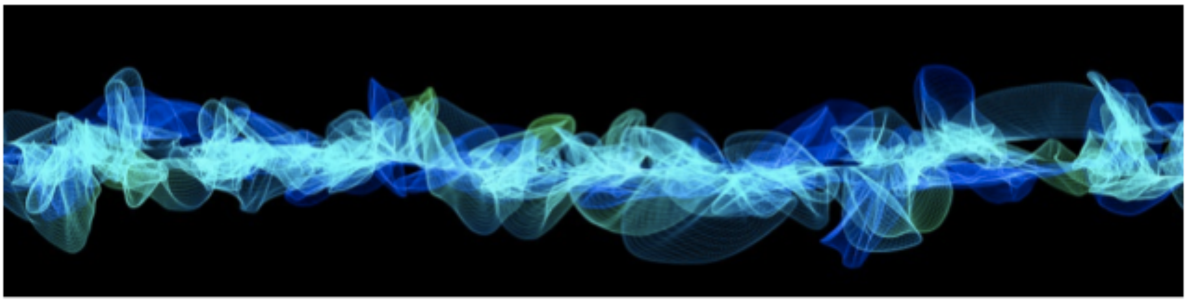

Figure 1. The phases of migraine.

Migraines are reported to be a severe risk factor for depression due their burden on patients. Migraines and major depression have been reported to be closely related, and their relationship and mutually influential role has been of interest to researchers. For example, Patten et al., (2008) researched whether major depression increases the risk of migraines. According to their study, the strength of the relationship between migraines and depression depends on age.

Proper healthcare is required to achieve more effective solutions in the future because, for example, health is declining in Finland, Europe and the United States. Working-age people whose work capacity is decreasing present major challenges to healthcare (Gustavsson et al., 2010; Haux, 2006; Olesen et al., 2012) Rapidly developing healthcare technology has resulted in more efficient and effective care, enabling people to remain fit for work for a longer time span. ICT permits more efficient sensor technology for healthcare by providing data regarding the status of individual wearers, which in turn enables better self-care (Chan et al., 2009; Haux, 2006; Ko et al., 2010).

Today, wearable sensors used to support health and well-being represent one of the most rapidly growing sectors in consumer electronics. The global value of this sector is estimated to reach nearly €34 billion by the year 2020, when it is anticipated that nearly 411 million smart, wearable devices will have been sold (CCS, 2016).

Wearable sensors can detect a person's mood and wellness, as reported by Zenosis et al., (2016). They also demonstrate that the measures monitored by the sensors are more accurate than results measured by person.

The sensors collect comprehensive health information and convert it into a digital format. Electrical, thermostatic, optical, chemical and genetic signals can be used by the sensor to monitor physiological, physical and cognitive health (Dargie and Poellabauer, 2010; Ko et al., 2010). Medical sensors are integrated into the devices, systems and environments, and their purpose is to sense the external world (Dargie and Poellabauer, 2010; HIS, 2013). Important measurable values for treatment are cardiograms, pulse, body temperature, blood pressure, oxygen saturation and daily activity. Sensor information is necessary to assess the patient's condition, determine the correct diagnosis and make decisions on treatment and future management (Alemdar and Ersoy, 2010; HIS, 2013; Ko et al., 2010).

Timpano et al., (2013) sought to eliminate unnecessary traveling for patients and their carers when seeking treatment. They proposed telemedicine, and also suggested that patients be encouraged to apply ICT techniques in several ways. Current ICT solutions allow for social networking, the preparation of treatment plans, virtual conferences and collaboration between families for people in need of healthcare as well as their caretakers.

3 Research Method

The current study was explorative in nature as very little knowledge was available about the use of body sensors to detect migraines or their pre-symptoms (Gable, 1994).

As noted by Jensen (2010), as an explicit category, surveys can be used to collect material, as can a research design different from other types of qualitative research. He listed four steps to conducting qualitative surveys: defining knowledge aims, sampling, data collection and analysis.

3.1 Data collection

The empirical material for the study was collected in September 2016 using an online survey via Webropol (webropolsurveys.com). The questions were based on the literature review; to evaluate their comprehensiveness, suitability and content, the questions were cross-checked by the Executive Director of the Finnish Society for Migraine. Based on the comments, the questionnaire was modified to add intelligibility and consistency to the questions. In addition, four questions were deleted. The questionnaire was accompanied by a cover letter that offered information about the study and its objectives. The final questionnaire included questions about the background of the respondents and their thoughts about migraine pre-symptom-related devices. In all, seven questions were asked in the questionnaire, all of which focused on the need to identify the pre-symptoms of migraine and the personal significance of treating migraines.

The questionnaire consisted of arguments to be valued, questions with multiple-choice answers and text boxes for free text. In total, 565 completed questionnaires were returned, all of which were adequate for the study.

The questionnaire contained background information questions to determine the gender and migraine type of the respondents, as well as whether they could detect the pre-symptoms of migraine, and if so, what pre-symptoms they could detect. The questions related to the device wanted to find out whether users are willing to use sensors to be used to detect migraine symptoms (see Table 1).

If you had a device that detects migraine pre-symptoms, would you use it?
If you answered 'yes' to the previous question, explain your answer in a few words.
On which part of the body would you prefer the device if you could choose?
Where would you like the device to be placed from the following?
What would you like the device to measure?
Why would you buy the device for yourself?
How should the device indicate an upcoming migraine attack?

Table 1. Device-related Questions

Table 1 lists questions related to the device, the answers to which comprised the results of this study. Questions related to the device were selected on the basis on previous studies. Based on the answers, we can find new opportunities to utilize sensor technology in treating migraine. After defining device issues, it was possible to demonstrate whether the migraine patients were willing to use the sensors, where they were willing to use the device, and how they would like to be notified of a future migraine attack.

3.2 Analysis of data

The responses were reviewed several times and then classified into two categories according to the original research question. The aim of the first review was simply to get an initial impression about the research material; afterwards, differences and similarities in the answers were assessed. Notes from the reviews were written into additional charts to support the analysis. After the first impression of the material, classes were identified, reorganised and renamed in accordance with the content. In addition, percentages and counts were used to describe the research material (see Lee and Want, 2003).

Background information was collected about sex, type of migraine, type of migraine medication and the number of migraine attacks. The responses were analysed and classified by typical signs and symptoms associated with migraine headaches. Next, the symptoms were classified as prodromal symptoms or major symptoms. Device-related answers were analysed based on the part of the body each respondent chose to wear the device. Furthermore, the desired measures and their frequency were derived from the answers. Finally, one of the most important goals was to determine how many migraine patients wanted to wear the sensors to identify and treat their migraine pre-symptoms.

4 Analysis

The survey was completed by 534 (94.5%) women and 31 (5.5%) men (see Table 2). At the time of the study, the relative proportions of women and men within the case society were unknown.

Gender	*N*	%
Female	534	94.5%
Male	31	5.5%

Table 2. Distribution by Gender

Table 3 shows the sums of different types of migraines in relation to the presence or absence of auras. Approximately one-half (48%) of the respondents suffered at least five migraine attacks per month, and were thus classified as heavy users of healthcare.

Migraine type	*N*	%
With aura	222	39.3
Without aura	296	52.4
I don’t know	47	8.3

Table 3. Migraine Type

When asked about suffering sensitivity to light, sensitivity to sound, smell sensitization, numbness of the face, visual field defects, including blinking lights, respondents revealed that they suffered many of these symptoms. According to the responses, 87.8% of the patients recognised such pre-symptoms of migraine. The most common reported symptoms included yawning, fatigue, slow thinking, difficulty finding words and visual disturbances.

To determine whether migraine patients would be willing to use a migraine-symptom-sensing device, several questions were asked. In general, the respondents were very open to this option, as illustrated in Table 4, which reveals that 88.9% of the respondents would be willing to use the device.

If you had a device that detected migraine pre-symptoms, would you use it?	*N*	%
Yes	502	88.9%
No	63	11.1%

Table 4. Willingness to Use the Device

The respondents were also asked if they would be willing to buy the device. More precisely, they were asked what circumstances would cause them to buy the device; in response, 269 persons (47.6%) mentioned physician recommendations or scientific support as a motivator to buy the device.

There were many reasons why most of the respondents (88.9%) were willing to use wearable sensors to detect imminent migraine attacks. Below are presented some of these reasons in respondents' own words:

'The device would help me to take the medicine in time and I could survive a migraine attack with Ibuprofen'.

'I could better plan my work, move any appointments, meetings and others. It would be easier to figure out why I'm irritated, tired, absent, etc. The device could help the timing of taking the medication. In working life, especially with frequent coping problems, it could be that the device would better manage these issues'.

'I would use it if the device recognised the oncoming migraine attack before I did. At that point, attack medicine (which is supposed to be given at a very early stage) would be useful (i.e., could get the migraine knocked down before it started'.

'It would help me to anticipate and better identify situations/issues that trigger migraines and may, in the future, prevent them. Occasionally, the pre-symptoms are not noticed in time, so the taking of the medication is also delayed. The device could also help with that'.

'Since I do not recognise the pre-symptoms, the device "which would do it" would be more than awesome. For example, a bracelet, like the much-used activity braces nowadays, would certainly be used. When I get an attack, it's so paralysing that if I could just avoid it/take the medicine on time/moderate it, it would be better than winning the lottery!'

'At night, I wake up with really hard migraine pain, so it would be tops if the device could tell in advance before going to bed that an attack is coming and I could take the medicine'.

'I often notice the warning symptoms too late and taking the medicine is often too late'.

'Sometimes the pre-symptoms are so confusing or mild that they are difficult to identify. The device could help prevent the initial attack'.

'You can take the medicine earlier and this way the pain will be less and the duration of the attack will decrease'.

'On the other hand, I have already learned to recognise the pre-symptoms, but still the attack is surprising'.

'When you notice the pre-symptoms as early as possible, the attack will not get bad because of taking the medication in time. Possibly the causing factor of the migraine would be found more easily'.

'I do not recognise the symptoms. Sometimes, I waste medicine when I'm not sure and because the medicines do not always work, this could help to identify the right symptoms and reduce unnecessary medication and time the premedication right'.

When respondents were asked on which part of the body they would like to attach the wearable device, as well as which measuring device was desirable, most preferred the 'hands and feet' (see Figure 2). Table 4 shows that the majority of respondents wanted the device to be attached to their wrists like a watch, or as a wristband or skin patch. The migraine patients felt it important that the device measured blood pressure, sleep quality, stress levels, pulse and pain intensity.

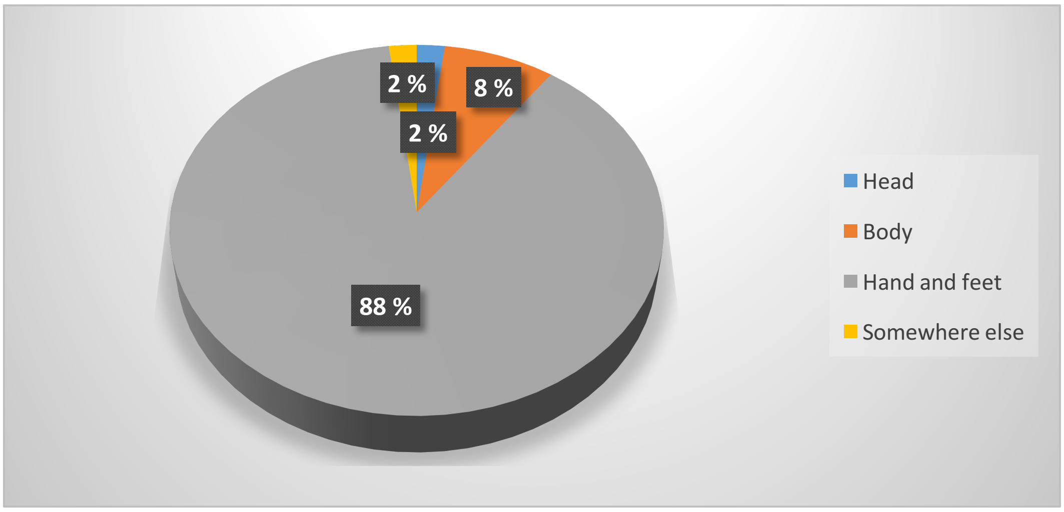

Figure 2. Preferred parts of the body for the wearable device.

Table 5 provides a more detailed picture of the parts of the body that were preferred by the patients. Based on the answers, it can be inferred that the patients were not afraid of other people seeing the wearable, as only eight patients mentioned the 'foot' as a good place for the sensor. The 'wrist' was by far the most popular part of the body, and one can assume that the current popularity of different activity bracelets might have influenced the responses. On the other hand, when asked whether the device should be unobtrusive, 315 respondents preferred it to be, while 250 did not mind if the device was visible or otherwise conspicuous.

Desired location for the device	*N*	%
Finger	94	17
Wrist	519	92
Head	16	3
Ankle	126	22
Stomach	23	4
Chest	51	9
Leg	15	3
Arm	94	17
Thigh	11	2
Foot	8	1
Somewhere else	22	4

Table 5. Preferred Parts of the Body for the Sensors

The way in which the device should alert the wearer about an imminent migraine attack varied by respondents as follows: by tone (36.1%), text (23.7%), light (14.3%), flashing lights (4.4%), emoji (9.4%) or some other sign (12.4%).

In all, 80% of migraine patients thought it would be a good idea if the device was available at, for example, a health centre, occupational healthcare clinic or a neurologist's office. With respect to potential collaboration on healthcare, 71% of respondents were willing to share information about migraine attacks with their physicians in real time, while 29% of respondents were unwilling to do so. Likewise, most of the respondents did not favour automatically forwarding migraine-related information to family members.

The respondents also favoured the possibility of including their personal details, such as weight, height, and sleep patterns, into the system; towards that end, they would like to see a smart application combined with the wearable device.

5 Discussion

The current study explored whether people suffering from migraines are interested in using wearable sensors to manage their symptoms, and especially for identifying early symptoms of their migraine attacks. As part of a wider research effort, the aim of this study was to determine what kinds of wearables the respondents were willing to use. The wider project studied whether it was possible to detect imminent migraine attacks by utilising intelligent systems or reading human biosignals. The findings suggest that by identifying and providing early treatment for pre-symptoms, migraine sufferers can improve their quality of life and reduce problems such as taking sick leave from work. We could directly reflect the background information to previous research.

The study also revealed that nearly one-half of people with migraines experience an aura and can recognise symptoms. The proportions of patients who experienced an aura (222), did not experience an aura (296), and did not know (47) were interesting since, according to Olesen et al., (1990), migraines are most often accompanied by an aura. This finding suggests further research from the sensor-enabled viewpoint, especially if patients are willing to use sensor-based wearables to identify initial symptoms and receive help prior to a potential major attack.

As a theoretical contribution, this study proposes that people with migraines who do not have an aura experience might suffer from headaches suddenly and unexpectedly. Accordingly, they might also suffer from pre-symptoms without recognising them as symptoms of an imminent migraine attack. On the other hand, sleep quality has been reported to be connected to migraine attacks, and insomnia is a major trigger for migraines. This has been reported to increase levels of body stress hormones (Bruni et al., 2008).

The generation of migraines has been studied by measuring the oxygen saturation of human biosignals, skin temperature, heart rate and activity (see, e.g. Olesen et al., 2012).

Altered human biosignals suggest changing situations and should be measured. Self-monitoring of one's own health condition has become popular due to the development of sensor technology and wireless data transfer in healthcare (Kohler et al., 2010). As another theoretical contribution, the current study revealed that patients are prepared to monitor their own health, and for this reason, the task of the healthcare sector should be to guide patients to observe their changing biosignals.

Healthcare technology has the potential to transform migraine patients from passive recipients to active participants who can identify, monitor and plan for their own symptoms. Sensors can thus be used to encourage patients to play an active role in promoting their own health (Arnrich et al. 2010; Wolbring & Leopatra 2013) Based on the results of this study, it can be concluded that migraine patients are more prepared to actively promote their own health. The study showed that migraine patients have the desire to anticipate the onset of a migraine.

Due to the seriousness of migraines as perceived by the patients themselves (but also in terms of costs to the healthcare sector) (see Kaattari et al., 2015; Patten et al., 2008), it is reasonable to seek solutions to reduce this burden. According to the current study, the patients were willing to use wearable sensors and were eager to obtain information early, before migraine attacks occurred; this is a valuable practical finding in terms of both healthcare and wearable manufacturers. As Zenosos et al., (2016) noted, measures monitored and identified by sensors can be more reliable than feelings and inklings experienced by people. Thus, the reliability of sensors, especially for predicting future attacks, is supported.

Arnrich et al., (2010) argued that doctors and nurses benefit from patients' continuous biosignal data collection much more than random sampling. In addition, the benefits of sensors include helping patients identify their physical and psychological activity levels (Clarke and Steele 2012). Migraine patients preferred the device to measure pulse, blood pressure, blood glucose, activity level, step number, stress level, quality of sleep, sleep rhythm, hormone concentration, body temperature and air pressure variation.

Studies have shown that 15% of women and 5% of men suffer from migraines. In women, the occurrence of migraines is associated with hormonal changes (Rasmussen et al., 1991), which indicates to researchers that women are more likely to suffer from migraines than men. Therefore, a larger number of women than men were surveyed in this study.

Furthermore, self-care needs to be developed and emphasised to reduce extensive and costly institutionalised care, and this approach can be greatly aided by new technology and intelligent systems. As reported by Timpano et al., (2013) and Oluwagbemi et al., (2016), intelligent systems have recently received more research attention.

Future studies are needed to determine how people suffering from migraines can benefit from monitoring their pre-symptoms via wearable devices, as such technology is developing at a rapid pace and more options are increasingly available to collect and share health-related information on the internet. Especially, due to the number of committed respondents in the current study, it would be worth continuing the study with these respondents as well as new respondents from other countries.

6 Conclusions

In conclusion, the current study was able to answer the research question addressing the nature and preferred location of wearable sensors from the perspective of migraine sufferers.

These initial findings are promising; based on them, one can argue that patients with migraines are willing to use intelligent systems with wearable sensors. The findings revealed that almost one-half of those suffering from migraines can be considered heavy users of healthcare services due to the number of migraine attacks they experienced. The respondents (565 in total) were members of the Finnish Society for Migraine, 89% of whom (Table 4) indicated that they would use a wearable device to warn them about pre-symptoms of migraine.

Moreover, one can argue that people who are willing to use wearable devices are also motivated to monitor their overall health and thus reduce the need for institutionalised healthcare. By identifying migraine’s pre-symptoms, the physical, mental and social health of the patient can be promoted, which can in turn greatly reduce healthcare costs. Moreover, because women are more affected by migraines than men, they may also be more willing to monitor their biosignals and share information.

The Finnish Migraine Association provides support to migraine patients. It should be noted that because the respondents were all members of this society, the study results are representative of only this group, not of Finland as a whole. It can be expected that most of the respondents suffered from migraines more than once per month and were therefore willing to find the best solution for detecting pre-symptoms of migraine as early as possible. Consequently, the results of this study may be biased and are non-generalisable.

Only a few studies have been carried out to measure the pre-symptoms of migraine; and because these studies were each very different, it is difficult to say how effective sensors are as a means of preventing migraines. Early intervention to treat migraine attacks can improve the quality of life of patients, enhance preventive care and reduce sick leave. The study found that some migraine patients do not necessarily recognise the pre-symptoms of migraine themselves. More studies are needed that can be used to estimate the long-term benefits and cost implications of sensors in migraine treatment.

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References

Alemdar, H. & Ersoy, C. (2010). Wireless sensor networks for health care: A survey. *Computer Networks,* 54(15), 2688-2710.

Arnrich, B., Mayora, O., Bardram, J. & Tröster, G. (2010). Pervasive healthcare. *Methods of Information in Medicine*, 49(1), 67-73.

Belam, J., Harris, G., Kernick, D., Kline, F., Lindley, K., McWatt, J., Mitchell, A. & Reinhold, D. (2005). A qualitative study of migraine involving patient researchers. *British Journal of General Practice*, 55(511), 87-93.

Berg, J. & Stovner, L. J. (2005). Cost of migraine and other headaches in Europe. *European Journal of Neurology*, 12(s1), 59-62.

Bruni, O., Russo, P. M., Ferri, R., Novelli, L., Galli F. & Guidetti, V. (2008). Relationships between headache and sleep in a non-clinical population of children and adolescents. *Sleep Medicine*, 9(5), 542-548.

Burstein, R., Collins, B. & Jakubowski, M. (2004) Defeating migraine pain with triptans: A race against the development of cutaneous allodynia. *Annals of Neurology*, 55(1), 19-26.

Burstein, R., & Woolf, C. J. (2000). Central sensitization and headache. J. Olsen, P. Tfelt-Hansen, & KMA Welch, The headaches, 125-131.

CCS. (2016). *CCS Insight* [Online]. Available from: www.ccsinsight.com/press/company-news/2516-wearables-momentum-continues, 2016.

Chan, M., Campo, E., Estève, D. & Fourniols, J. Y. (2009). Smart homes-current features and future perspectives. *Maturitas*, 64(2), 90-97.

Clarke, A., & Steele, R. (2012, August). Summarized data to achieve population-wide anonymized wellness measures. In Engineering in Medicine and Biology Society (EMBC), 2012 Annual International Conference of the IEEE (pp. 2158-2161). IEEE.

Dargie, W. & Poellabauer, C. (2010). Motivation for a network of wireless sensor nodes. *Fundamentals of Wireless Sensor Networks*, 1-16.

Gable, G. G. (1994). Integrating case study and survey research methods: An example in information systems. *European Journal of Information Systems*, 3(2), 112-126.

Gustavsson, A., Jonsson, L., Fillit, H., Johansson, G., Wimo, A., & Winblad, B. (2010). IPECAD5—Fifth international pharmaco-economic conference on Alzheimer's disease. JNHA-The Journal of Nutrition, Health and Aging, 1-3.

Haux, R. (2006). Health information systems – past, present, future. *International Journal of Medical Informatics,* 75(3), 268-281.

IHS. (2013). Headache Classification Committee of the International Headache Society (IHS). The international classification of headache disorders, (beta version). *Cephalalgia*, 33(9), 629-808.

Jansen, H. (2010). The logic of qualitative survey research and its position in the field of social research methods. In: *Forum: Qualitative Social Research*. Vol. 11. No. 2.

Kaattari, A., Tiirinki, H., Paasivaara, L., Nordstrom, T. & Taanila, A. (2015). Major user of primary health care services in Northern Finland birth cohort. *Social Medication Magazine*, 52(3), 191-200.

Kallela, M. (2005). What's new in migraine pathophysiology and genetics. *Duodecim*, 121(6), 665-74.

Ko, J., Lu, C., Srivastava, M. B, Stankovic, J. A., Terzis, A. & Welsh, M. (2010). Wireless sensor networks for healthcare. *Proceedings of the IEEE*, 98(11), 1947-1960.

Koehler, F., Winkler, S., Schieber, M., Sechtem, U., Stangl, K., Böhm, M., Boll, H., Kim, S., Koehler, K., Lücke, S., Honold, M., Heinze, P., Schweizer, T., Braecklein, M., Kirwan B-A., Gelbrich, G. & Anker, S. (2010). Telemedical Interventional Monitoring in Heart Failure (TIM-HF), a randomized, controlled intervention trial investigating the impact of telemedicine on mortality in ambulatory patients with heart failure: study design. European journal of heart failure, 12(12), 1354-1362.

Lee, S. & Wang, J. (2003). *Statistical Methods for Survival Data Analysis* (Vol. 476). John Wiley & Sons.

Lymberis, A. & De Rossi, D. E. (2004). *Wearable eHealth Systems for Personalised Health Management: State of the Art and Future Challenges*. Amsterdam: IOS Press.

Olesen, J., Friberg, L., Olsen, T. S., Iversen, H. K., Lassen, N. A., Andersen, A. R. & Karle, A. (1990). Timing and topography of cerebral blood flow, aura, and headache during migraine attacks. *Annals of Neurology*, 28(6), 791-798.

Olesen, J., Gustavsson, A., Svensson, M., Wittchen, H. U. & Jönsson, B. (2012). The economic cost of brain disorders in Europe. *European Journal of Neurology*, 19(1), 155-162.

Oluwagbemi, O., Oluwagbemi, F. & Ughamadu, C. (2016). Android Mobile Informatics Application for some Hereditary Diseases and Disorders (AMAHD): A complementary framework for medical practitioners and patients. *Informatics in Medicine Unlocked*, 2, 38-69.

Pagán J., Orbe, D., Irene M., Gago, A., Sobrado, M., Risco-Martin, J. L., ... & Ayala, J. L. (2015). Robust and accurate modeling approaches for migraine per-patient prediction data from ambulatory. *Sensors*, 15(7), 15419-15442.

Patten, S. B., Williams, J. V., Lavorato, D. H., Modgill, G., Jetté, N. & Eliasziw, M. (2008). Major depression as a risk factor for chronic disease incidence: Longitudinal analyses in a general population cohort. *General Hospital Psychiatry*, 30(5), 407-413.

Rasmussen, B. K., Jensen, R., Schroll, M. & Olesen, J. (1991). Epidemiology of headache in a general population—a prevalence study. *Journal of Clinical Epidemiology*, 44(11), 1147-1157.

Timpano, F., Bonanno, L., Bramanti, A., Pirrotta, F., Spadaro, L., Bramanti, P. & Lanzafame, P. (2013). Tele-health and neurology: What is possible? *Neurological Sciences*, 34(12), 2263-2270.

Wolbring, G. & Leopatra, V. (2013). Sensors: Views of staff of a disability service organization. *Journal of Personalized Medicine,* 3(1), 23-39.

Zenonos, A., Khan, A., Kalogridis, G., Vatsikas, S., Lewis, T., & Sooriyabandara, M. (2016, March). HealthyOffice: Mood recognition at work using smartphones and wearable sensors. In Pervasive Computing and Communication Workshops (PerCom Workshops), 2016 IEEE International Conference on (pp. 1-6). IEEE.