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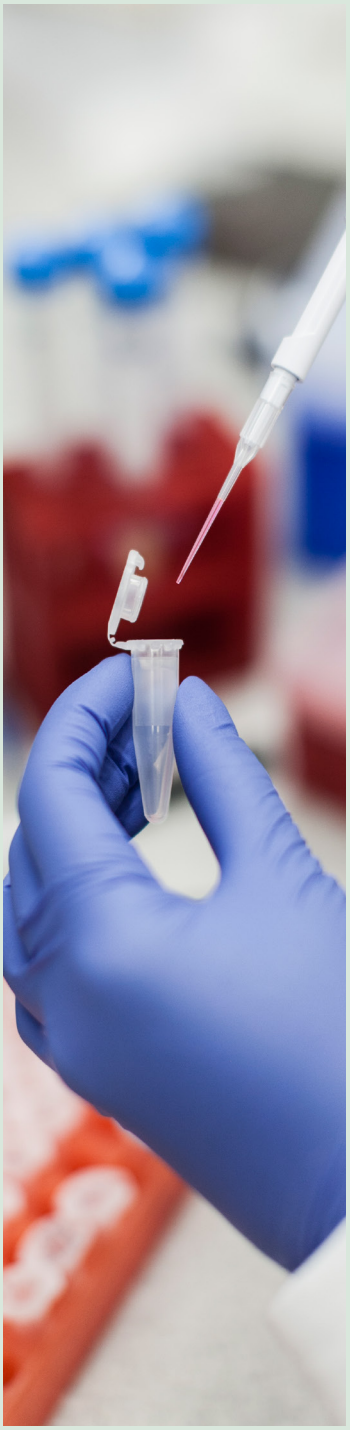

DIGITAL HEALTH PLATFORMS FOR THE EFFECTIVE MANAGEMENT OF CHRONIC DISEASES

Abstract

Globally, the economic burden of non-communicable chronic diseases is on the rise. This presents a significant challenge for patients, healthcare systems, and governments worldwide. Reactive, traditional, and in-clinic patient care conducted on an intermittent basis is fast shifting to a new model that is personalized, preventative, predictive, and participatory. Digital health platforms integrate information from regulated Class I, II, and III medical devices, IoT wearables, and mobile apps, and hold the key to the digital transformation of the life sciences industry.

This white paper reviews current challenges in the management of chronic conditions like cardiovascular diseases, diabetes mellitus, chronic pain, and spinal disorders, and discusses how digital platforms and technologies can be utilized to help patients effectively self-manage these. In particular, we review the role of key technologies underlying digital health platforms, such as artificial intelligence and machine learning, in providing customized insights tailored to each patient. Providing services on top of their existing portfolio of medical devices and pharmaceutical products enables life sciences companies to establish lasting rapport with patients and represents a unique opportunity for the industry to go beyond its traditional manufacturing role.

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Introduction

Medical care has made rapid strides in the last couple of decades. The speed with which the life sciences fraternity reacted to the COVID-19 pandemic with the right guidelines, appropriate treatment protocols, and accelerated development of vaccines is testimony to this fact. The pandemic also brought another fact to the forefront – the use of technology and digital devices is inevitable in the future. Advancements in the field of health care in conjunction with digital health platforms point the way forward to ensure rapid care and long-term monitoring of multiple health conditions afflicting us today and beyond. This paper looks at 4 such health conditions – cardiovascular diseases, diabetes mellitus, chronic pain, and spinal disorders – where digital health platforms and technologies are making a significant difference.

Cardiovascular diseases account for a huge percentage of fatalities globally. In the first section, we explore how digital tools are helping with the management and treatment of cardiovascular diseases.

Digital solutions to improve cardiovascular disease outcomes

Cardiovascular diseases (CVDs) are the leading cause of death worldwide, accounting for 17.9 million deaths in 2019. Heart attacks and strokes were the primary causes of mortality, making up 85% of deaths.[1] In the coming years, the burden of CVDs is expected to increase, imposing greater strain on the health expenditure of governments globally. It is estimated that CVDs will affect more than 40% of the population of the United States by 2030. The associated cost of diagnosis and treatment is projected to reach US $622 billion by 2025.[2]

Approximately 50% of CVD risk can be attributed to physical inactivity, smoking, and comorbidities such as diabetes and obesity.[3] While the development of CVDs can be influenced by unmodifiable risk factors such as age, ethnicity, and family history,[4] there are many modifiable risk factors that can be controlled through lifestyle adjustments and timely interventions.

Challenges associated with the self-management of CVDs

Though governments, healthcare payers, and providers are grappling with the burden of CVDs, the strong influence of modifiable risk factors that contribute to the development of CVDs can be leveraged to inhibit disease onset. A substantial body of research has demonstrated the importance of a healthy diet and regular exercise to reduce the risk of CVDs.5,6,7 An unhealthy diet is strongly associated with the development of coronary heart disease, characterized by plaque deposition in the vital blood vessels that supply the heart with oxygen.[5] Among high-risk adults, dietary interventions have improved CVD risk factors.[8] Similarly, physical activity is associated with improvements in CVD risk factors such as hypertension, insulin resistance, and elevated blood lipid levels.[5]

Medication is integral to effectively manage CVDs. However, research indicates that the complexity of medication regimens poses challenges to a patient's ability to adhere to their prescriptions.[9] A study of 56 patients with uncontrolled hypertension found only 50% of individuals as having hypertension truly unresponsive to treatment. Clinically significant reductions in blood pressure were observed among the remaining 50% of these patients when administered their prescribed medications regularly by clinical staff.[10]

In addition to medication adherence, helping patients maintain a healthy diet and exercise regimen is critical for self-managing CVDs. However, a study found that among 759 US adults with self-reported coronary heart disease, only 17% achieved recommended exercise levels, with just 7% having attained the recommended dietary salt intake.[11] These results make it clear that measures must be implemented to assist patients in maintaining healthy lifestyle habits.

Digital tools are being trialed to help patients self-manage CVDs and assist them with tracking adherence to medication, nutrition, and exercise regimens. Additionally, medical device companies are also providing digital companions with their products for a more personalized user experience.

The role of digital tools in CVD care

Given the significant burden of CVDs on healthcare systems worldwide, there is growing interest in implementing digital solutions that assist patients in self-managing their conditions. Digital health solutions such as mobile apps and remote monitoring devices have demonstrated encouraging efficacy in improving CVD risk factors and promoting better lifestyle management among cohorts with low to moderate CVD risk.[3] A meta-analysis of nine studies demonstrated that the risk of adverse CVD outcomes was reduced by 39% in the digital health intervention group compared to patients receiving normal care.[12] Research has also shown the effectiveness of digital interventions in improving physical activity, diet, and medication adherence.[3]

However, there is limited evidence to suggest that digital interventions alone can ameliorate blood lipid levels, blood pressure, blood sugar levels, or body mass index.[3] This suggests that the role of digital solutions is to assist patients with lifestyle management to complement the clinical outcomes achieved through medications and medical devices.

CVD related implants like Cardiac Resynchronization Therapy(CRT) Implants and Implantable Cardioverter-Defibrillator Implants(ICD), traditionally did not record any data. The current generation of CVD implants qualify as medical IoTs. Bluetooth technology is now enabling data generated from CVD implants to be viewed on a patient's smart phone as well as the Clinic's dashboard.[13] This data can be easily transmitted from smart phones to a secure network without the need for traditional bedside monitors as transmitters. Patients using Bluetooth-enabled pacemakers coupled with a mobile app recorded a success rate of 94.6% for scheduled transmissions. This was significantly higher than the 56.3% and 77% success rate among patients using manual or wireless transmission methods via a bedside monitor.[13]

Trials conducted to investigate the effect of digital health interventions on hypertension management have also demonstrated that digital solutions induced a more potent reduction in blood pressure, compared to conventional, in-office monitoring.[14] Patients assigned to the digital medicine group were asked to purchase a wireless blood pressure unit, which provided monthly reports detailing recommended actions and their CVD risk via their smart phones. After 90 days, 70% of patients in the digital medicine group had controlled blood pressure, compared to only 31% among patients who received normal care.[14] Compared to an average of 0.8 blood pressure readings in the normal care group, an average of 55 readings were taken in the digital medicine group, demonstrating higher patient engagement.[14]

While CVDs pose a huge strain on healthcare systems worldwide, lifestyle adjustments and guided medication can go a long way in managing the disease. However, treatment regimens can be complex, making it difficult for patients to follow prescribed routines unmonitored. Digital health devices, and platforms that integrate medical device data and medication, dietary and activity trackers to generate actionable insights in one place ensure that patients follow regimens to effectively self-manage their condition. This provides CVD patients the opportunity for a better quality of life while reducing the burden on healthcare systems.

Similar to CVDs, diabetes is a condition that needs close monitoring and therefore places a huge burden on patients and healthcare systems. Next, we will see how diabetes management can be made more effective with hybrid healthcare. A combination of regular medical care coupled with digital devices for monitoring and analysis can change the lives of patients with diabetes.

The future of diabetes care: a digital perspective

Globally, diabetes mellitus (DM), characterized by high blood sugar levels, is one of the most common chronic diseases. In the US, the medical cost of diabetes is estimated to be US $237 billion annually[15] and is one of the fastest growing economic burdens on the healthcare system.[16] When poorly managed, DM can lead to other complications such as retinopathy, diabetic foot, nephropathy, or CVDs. This is because chronic hyperglycemia can damage tissues and in severe cases, result in organ failure. Blindness, renal failure, and foot amputations are all long-term complications associated with chronic hyperglycaemia.[17]

The two most common types of diabetes are Type 1 and Type 2 DM. Type 1 DM is characterized by deficient insulin production, with individuals normally diagnosed during childhood or adolescence. The treatment for Type 1 DM relies on the daily administration of insulin delivered via multiple injections or an insulin pump.[17,18]

Type 2 DM, however, is caused by the body's cells becoming less responsive to insulin. This phenomenon, known as insulin resistance, is strongly associated with modifiable risk factors, such as a sedentary lifestyle, an unbalanced diet, and obesity.[19] Early-stage Type 2 DM is treated using oral medications to improve insulin absorption or secretion. However, insulin administration may also be required, particularly in late-stage Type 2 DM.[17] A balanced diet, weight loss, and close monitoring can help manage Type 2 DM, preventing further progression and improving quality of life. With good lifestyle management, individuals with Type 2 DM can maintain normal blood sugar levels without medication.[20]

Digital solutions to manage diabetes

Effective management of DM requires patients to have a high degree of health literacy to track their daily carbohydrate intake, monitor their blood sugar levels, and maintain stringent nutrition and exercise regimens.[21] This need to track key health indicators and adhere to complex treatment plans can be burdensome for many patients.

Digital health platforms can be used for lifestyle management for patients with Type 2 DM; however, for patients with Type 1 DM, digital technologies can aggregate and analyze data from insulin pumps and continuous glucose monitors to generate condition-specific insights in addition to lifestyle management. Though in recent times clinicians are also taking advantage of insulin pumps and continuous glucose monitors for Type 2 DM patients. This allows Digital Health Platforms to help manage this chronic condition, just like Type 1 DM patients.

Traditionally, the self-management of blood sugar levels has involved using the fingerstick approach. However, such methods can be painful when multiple measurements are taken every day.[21] Newer techniques, such as continuous and flash glucose monitoring, where sensors are positioned subcutaneously, or on the upper arm have been developed for Type 1 DM.[22,23] These medical devices enable real-time monitoring of blood sugar levels without the need for finger-pricking. Measurements from continuous blood glucose monitors can be transmitted to a patient's smart phone, smart watch, or cloud.[24] These devices improve glycemic control and reduce incidences of hypoglycemia more effectively compared to standard blood glucose monitoring among children and adults with Type 1 DM.[25]

Technology also plays a vital role in automated insulin delivery systems, which consist of a continuous blood glucose monitor and an insulin pump. An integrated algorithm uses blood glucose readings to calculate the optimal dose of insulin to be delivered and predicts incidences of hyperglycaemia.[24] Though automated insulin delivery systems still rely on patients to input their scheduled mealtimes and planned carbohydrate intake, the system mimics the function of the pancreas to simplify the management of DM.[24]

Digital clinics: the future of patient care

In coming years, DM care will consist of a combination of in-person and virtual care, with technology playing an increasingly important role. A huge amount of patient data is being generated from smart devices such as glucose monitors, insulin pumps, wearables, portable ECGs, and even socks with smart capabilities.[26] This large quantity of data generated is advantageous to train machine learning (ML) algorithms to improve the accuracy of predictive analytics.

The use of artificial intelligence (AI) and ML algorithms to analyze patient-generated data enables real-time monitoring of symptoms and the early detection of adverse events, to serve as a personal assistant for patients with DM.[26] Variations in key health indicators can be communicated to clinicians, alerting them to concerning trends, which helps them effect modifications to treatment plans.[27]

The widespread use of digital tools for managing diabetes has also led to the emerging field of e-epidemiology, where patient outcomes are monitored based on data generated from connected devices.[26] This enables the identification of digital biomarkers associated with disease onset, elucidates the effect of other comorbidities on the severity of DM, and detects novel biological pathways that contribute to disease development. While the digital clinic is not a replacement for in-person care, technology that facilitates the analysis of data generated from connected devices will enable more holistic patient care, where treatment is guided by multiple parameters.

Hybrid healthcare is the way forward

Good management of DM is imperative to prevent the onset of severe complications such as blindness, gangrene, and multiple organ failure that can accompany disease progression. Smart devices and wearables will become integral to maintain glycemic control, offering several benefits that go beyond monitoring with the traditional fingerstick approach. Driven by AI and ML algorithms, predictive analytics based on data generated from smart devices will reduce hospitalizations induced by dangerous hyper or hypoglycemia. Thus, a hybrid model of patient care, consisting of anywhere-anytime digital clinics coupled with in-person consultations, will likely be the future of DM management.

Regardless of the disease, patients must contend with pain in various forms. Most chronic diseases have side effects or fallouts in the form of chronic pain. Modern lifestyles too lead to several chronic pain conditions. In the next section, we will discuss how digital intervention can go a long way in helping patients manage and cope with debilitating pain.

Chronic pain management: digital tools for support

CVDs and diabetes management are two use cases where digital health tools have attracted significant attention. However, chronic pain, which is estimated to affect 20% of individuals worldwide,[28] represents another opportunity for the implementation of digital solutions. In addition to the expense of medical treatment, loss of wages and productivity are among the many indirect costs incurred due to chronic pain.[29]

Chronic pain can arise from injury, surgery, musculoskeletal conditions, or cancer, and may result in mobility issues and mood changes.[30,31] Complications from diabetes, arthritis, and stroke are other common causes of chronic pain, particularly among the elderly.[32] The physical impediments caused by chronic pain can lead to difficulties at work and affect an individual's ability to maintain strong social connections. Good pain management should control pain to allow individuals to complete their daily activities.[31] While medication is an integral component of managing chronic pain, other strategies such as exercise therapy are key to the long-term management of chronic conditions.[30] Digital health platforms provide the necessary guidance for patients following exercise regimens and can play the role of a virtual coach to increase patient engagement.

Digital health platforms as a virtual coach for exercise therapy

A large body of scientific evidence has demonstrated the benefits of long-term exercise on chronic low back pain,[33,34] chronic neck pain,[35] and neuropathic pain.[36,37] Additionally, exercises improve physical function as well as mood, and prevent CVDs, neurodegenerative conditions, and bone diseases that may further exacerbate pain.[28]

Exercises that stabilize the spine and strengthen the core can build strength and endurance in muscle groups that support the back to manage chronic low back pain. This is particularly important since atrophy and other structural changes are often seen in these muscle groups in chronic low back pain, resulting in weaker muscles more prone to fatigue.[38]

Digital platforms can increase patient engagement and ensure that patients complete exercises correctly as per schedule. Access to demonstration videos for exercises can help patients follow their healthcare provider's instructions, preventing injuries caused by poor form. Maintaining high patient engagement is especially critical during the initial stages of exercise training when a short-term exacerbation of pain may be experienced.[39] Without close supervision, patients are unlikely to complete programs, resulting in a sedentary lifestyle that perpetuates a vicious cycle of increasing pain.[28] Since direct supervision by a healthcare professional over a patient's pain management is not always possible, digital platforms can play an increasingly vital role in engaging patients. Digital tools can help patients progress beyond the early stages of exercise training to establish positive habits.

Tracking pain using digital diaries

One of the most difficult aspects of effective pain management is the accurate baseline assessment of patients. These assessments, which consist of physical examinations and self-reported pain ratings, are used to guide treatment plans and monitor patient progress.[31] Patients can find it difficult to remember and report how they felt over an extended period of time during a doctor's appointment. A digital diary where patients can log their symptoms helps pinpoint the start and end dates of experiencing pain, creating an accurate record to guide the development of a personalized treatment plan.[40]

Digital tools can also be used to set timelines to fulfil specific goals in a pain management plan. This facilitates more accurate monitoring of patient progress and builds rapport between patients and clinicians. Digital diaries promote active engagement with patients to provide feedback and be involved in modifications to their treatment plan.

There are several key features of digital platforms that patients with chronic pain find particularly important:

- **Access to educational resources:** A survey of twenty chronic pain patients and five spouses found that individuals wanted to learn more about their condition and lifestyle adjustments such as exercise, sleep, and nutrition, as well as coping strategies for depressive and anxious thoughts.[41] Not being able to access reliable information regarding their condition led to patient distress, particularly during the initial stages of their condition. Though many turned to the Internet for answers, concerns over misinformation highlight the importance of a digital platform, where reliable patient education materials are easily accessible.[41]
- **On-demand support:** Patients want more contact with their healthcare provider, but they feel that traditional office hours present an accessibility barrier, since help could be required anytime. Patients with chronic pain have expressed interest in digital solutions to access on-demand support, with the ability to log their pain, mood, sleep, and activities to acquire better insight into their own coping mechanisms.[41]
- **Ease of use:** While user-friendliness is vital to any digital tool, ease of navigation is particularly critical for platforms aimed at chronic pain patients, since their condition can make it more challenging to engage in behavioral and cognitive activities.[42]

Chronic pain is a debilitating condition that can lead to physiological and psychological consequences. Digital health platforms can provide patients with daily, on-demand guidance. From serving as a virtual coach by assisting patients with exercise therapy, to a digital diary for individuals to log their pain experience, digital platforms serve as a tool for the effective self-management of chronic pain. In addition, digital tools can generate insights for clinicians to monitor patient progress and optimize pain management strategies.

Chronic pain is a side effect of many medical conditions. Certain persistent pain conditions need very specific interventions to help patients lead a comfortable life. In the last section, we will explore how digital platforms and devices can support chronic pain management in spinal care.

Digital support for spinal care

Spinal disorders are among the many conditions that can cause chronic pain and become more common with increasing age.[43] With the population of individuals over the age of 65 expected to almost double by 2040 in the US, the economic toll of spinal disorders, which ranks among the most expensive conditions to treat,[44] is also projected to increase.[43]

Low back pain caused by spinal disorders is one of the most crippling conditions.[45] With its prevalence correlated with increasing age, the management of spinal disorders among the elderly will be of utmost importance in coming years.

For patients who do not respond to medication and back surgery, an implantable spinal cord stimulator may be required to relieve low back pain, in conjunction with exercise, medication, and relaxation strategies.[46]

However, the use of spinal cord stimulators can have highly variable patient outcomes. According to figures from 2017, suboptimal outcomes were reported for a quarter of the 100,000 spinal cord stimulators implanted worldwide.[47] When integrated with digital health platforms, spinal cord stimulators can help healthcare providers monitor device usage patterns and identify concerning trends in patient-generated data that need to be addressed, leading to better patient outcomes.

Spinal cord stimulators for pain management

Spinal cord stimulators are implantable medical devices that deliver an electrical current to the spinal cord to provide pain relief. Low-level electricity is delivered, with the electrical dosage controlled by an external programmer with settings pre-programmed by a doctor.[48]

The electrodes delivering electricity to the spinal cord are fixed in the epidural space between the outermost membrane of the spinal cord and the vertebral wall.48 However, a key challenge is that the position of the spinal cord within the cerebrospinal fluid can be altered by movement, coughing, or breathing.[49] Though the magnitude of positional changes may be minor, even miniscule changes in the distance between the spinal cord and electrodes can lead to substantial changes in the electrical current delivered. This directly impacts the extent of nerve fiber stimulation and thereby, pain relief.[49]

The closed-loop system advantage

Many existing spinal cord stimulators operate as an open-loop system, where the extent of nerve fiber stimulation in response to the electrical current administered is not measured.[50] Additionally, no adjustments are made to the initial stimulation current. This leads to fluctuations in spinal cord activation due to movement or involuntary actions and can result in suboptimal or unpredictable pain inhibition.[49]

Recently developed closed-loop systems monitor the extent of nerve fiber activation and auto-adjust the stimulation current delivered to the spinal cord. By measuring fluctuations in spinal cord activation, the device can adjust the initial electrical dosage, to maximize the amount of time nerve fiber stimulation remains within the therapeutic window.[49,50] This feedback system is powered by algorithms integrated with the device.[48]

A landmark study published in 2019 investigated whether pain inhibition differed between two groups of patients with chronic intractable back and leg pain when the same spinal cord stimulator was deployed either using its closed-loop or open-loop settings.[49] Three months after device implantation, 82% of patients in the closed-loop group experienced at least a 50% reduction in overall pain, compared to 60% of individuals in the open-loop group. At 12 months, patients utilizing the closed-loop setting experienced more consistent nerve stimulation, with spinal activation remaining within the therapeutic target range 95.2% of the time, compared to only 47.9% of the time among patients utilizing the open-loop setting.[49]

Closed-loop stimulators for spinal pain can be integrated with digital health platforms to monitor device usage and trends in patient-generated data. These platforms, powered by AI and ML, can produce activity reports that highlight key trends in user statistics. Real-time data facilitates better monitoring of the patient response, allowing clinicians to adjust the spinal cord stimulator's programmed settings to achieve maximal pain relief.

Digital health platforms as a companion for spinal cord stimulators

Digital health platforms can enrich the user experience by integrating and analyzing data generated by spinal cord stimulators. These include:

- **Replacing the handheld programmer with a smart phone controller:** Compared to a traditional handheld device, the ability to control the delivery of electricity from a smart phone is vastly more convenient for patients. While these settings should be pre-programmed by a physician, patients can easily adjust parameters within the pre-defined range set by their doctor to maximize their comfort.
- **Personalized patient reports:** Using AI and ML, patient data generated by the spinal cord stimulator can be analyzed and viewed on a smart device. Clinicians can quantify outcomes by tracking device usage, the amount of time spinal cord stimulation remains within the therapeutic window, and nerve fiber stimulation levels over a specific timeframe. Access to this information can help clinicians re-adjust device parameters to optimize pain relief and modify treatment plans.
- **Device alerts:** Good maintenance of a spinal cord stimulator is critical for device longevity. Alerts can notify patients to recharge their device and enable individuals to seek immediate assistance from healthcare professionals to troubleshoot device issues. Digital tools can also provide patients with access to videos that teach them how to care for their device and the necessary precautions to take when living with a spinal cord stimulator.

As the aging population increases, spinal disorders and related chronic pain management will become a global challenge. The way forward is using patient-generated data to understand the efficacy of the current treatment and make prudent modifications to treatment plans. Spinal cord stimulators, in conjunction with digital health platforms, provide a technology-driven approach to monitor and better manage treatment outcomes. Integrated digital health platforms can provide a continuously engaged and holistic solution to spinal pain management and overall patient care.

Conclusion

Chronic disease management relies on the patient's ability to adhere to medication, exercise, and nutrition regimens. Effective management of chronic conditions requires patients to have a high degree of health and nutrition literacy to track and monitor medicine, diet, and exercise regimens. This places a complex burden on patients already grappling with chronic conditions.

Digital health platforms serve two primary purposes:

1. Integrate and analyze data from FDA and EMA-regulated Class I, II and III medical devices to generate condition-specific, customized insights.
2. Aggregate and analyze data from wearables and mobile apps, allowing patients to track their medication, activity, and dietary regimens, to generate condition-agnostic insights for better lifestyle management.

These insights, tailored to the needs of chronic disease patients, facilitate the remote monitoring of patient symptoms by clinicians to easily evaluate progress using quantifiable and objective health metrics.

Digital health platforms can play a critical role in the effective management of chronic conditions such as cardiovascular diseases, diabetes mellitus, chronic pain, and spinal disorders. By seamlessly integrating real-time data from medical devices and wearables as well as other digital devices, they enable clinicians to remotely monitor patient progress, and generate customized insights to help individuals self-manage their chronic conditions for a better quality of life.

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Gurdeep Singh Rooprai has been providing IT solutions and consulting services to clients at Infosys for more than 20 years now. Keeping pace with the industry, his focus has been on digital, automation, analytics, IoT, security, cloud, connected health, XR and more. Working with multiple partners, he has successfully managed a variety of engagements that drive value for clients such as cost-of-care data aggregation, pharma sales, digital factory for sales/ marketing asset creation, next-gen manufacturing and many more. Now, one of his key interests is the Digital Health Platform for the Life Sciences industry and he works with a passionate group of experts to understand the space better.

References

1. World Health Organisation. Cardiovascular diseases (CVDs) [Internet]. World Health Organisation, 2021 [updated 11 June 2021; cited 8 Dec 2021]. Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)
2. Heidenreich PA, Trogdon JG, Khavjou OA, Butler J, Dracup RN, et al. Forecasting the Future of Cardiovascular Disease in the United States, Circulation. 2011 Jan 24; 123: 933-944.
3. Akinosun AS, Polson R, Diaz-Skeete Y, De Kock JH, Carragher L, Leslie S, et al. Digital Technology Interventions for Risk Factor Modification in Patients With Cardiovascular Disease: Systematic Review and Meta-analysis. JMIR Mhealth Uhealth. 2021 Mar 3;9(3): Article no.: e21061.
4. British Heart Foundation. Session 4 – Modifiable and non-modifiable risk factors and Session 5 – Introduction to screening [Internet]. London: British Heart Foundation, n.d. [cited 6 Dec 2021]. Available from: https://www.bhf.org.uk/~/media/files/publications/healthy-hearts-and-chest-pain-kits/4-6-risk-factors-for-chd.pdf
5. Doughty KN, Del Pilar NX, Audette A, Katz DL. Lifestyle Medicine and the Management of Cardiovascular Disease. Curr Cardiol Rep. 2017 Oct 4;19(11): Article no. 116.
6. Cornelissen VA, Smart NA. Exercise training for blood pressure: a systematic review and meta-analysis. J Am Heart Assoc. 2013 Feb 1;2(1): Article no. e004473.
7. Ford ES, Bergmann MM, Kröger J, Schienkiewitz A, Weikert C, Boeing H. Healthy living is the best revenge: findings from the European Prospective Investigation into Cancer and Nutrition-Potsdam study. Arch Intern Med. 2009 Aug 10;169(15):1355-1362.
8. Saneei P, Salehi-Abargouei A, Esmaillzadeh A, Azadbakht L. Influence of Dietary Approaches to Stop Hypertension (DASH) diet on blood pressure: a systematic review and meta-analysis on randomized controlled trials. Nutr Metab Cardiovasc Dis. 2014 Dec;24(12):1253-1261.
9. Hamrahian SM. Medication Non-adherence: A Major Cause of Resistant Hypertension. Curr Cardiol Rep. 2020 Sep 10;22(11): Article no. 133.
10. Hameed MA, Tebbit L, Jacques N, Thomas M, Dasgupta I. Nonadherence

to antihypertensive medication is very common among resistant hypertensives: results of a directly observed therapy clinic. J Hum Hypertens. 2015 May 7;30(2):83–89.

11. Tang L, Patao C, Chuang J, Wong ND. Cardiovascular risk factor control and adherence to recommended lifestyle and medical therapies in persons with coronary heart disease (from the National Health and Nutrition Examination Survey 2007-2010). Am J Cardiol. 2013 Oct 15;112(8):1126-1132.
12. Widmer RJ, Collins NM, Collins CS, West CP, Lerman LO, Lerman A. Digital health interventions for the prevention of cardiovascular disease: a systematic review and meta-analysis. Mayo Clin Proc. 2015 Apr;90(4):469-480.
13. Tarakji KG, Zaidi AM, Zweibel SL, Varma N, Sears SF, Allred J, et al. Performance of first pacemaker to use smart device app for remote monitoring. Heart Rhythm O2. 2021 Oct; 2(5): 463-471.
14. Milani RV, Lavie CJ, Bober RM, Milani AR, Ventura HO. Improving Hypertension Control and Patient Engagement Using Digital Tools. Am J Med. 2017 Jan; 130(1):14-20.
15. Centers for Disease Control and Prevention. National Diabetes Statistics Report 2020 – Estimates of Diabetes and Its Burden in the United States [Internet]. U.S. Department of Health and Human Services. Atlanta: Centers for Disease Control and Prevention, 2020 [cited 14 Dec 2021]. 30 p. Report no.: 2. Available from: https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf
16. Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge AW, et al. IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. Diabetes Res Clin Pract. 2018 Apr; 138: 271-281.
17. Contreras I, Vehi J. Artificial Intelligence for Diabetes Management and Decision Support: Literature Review. J Med Internet Res. 2018 May; 20(5): Article no. e10775.
18. Peters AL, Ahmann AJ, Battelino T, et al. Diabetes technology-continuous subcutaneous insulin infusion therapy and continuous glucose monitoring in adults: An Endocrine Society clinical practice guideline. J Clin Endocrinol Metab 2016 Nov 1; 101(11): 3922–3937.
19. Kolb H, Martin S. Environmental/lifestyle factors in the pathogenesis and prevention of type 2 diabetes. BMC Med. 2017 Jul 19;15: Article no. 131.
20. Taylor R, Al-Mrabeh A, Zhyzhneuskaya S, Peters C, Barnes AC, Aribisala BS, et al. Remission of Human Type 2 Diabetes Requires Decrease in Liver and Pancreas Fat Content but Is Dependent upon Capacity for β Cell Recovery. Cell Metab. 2018 Oct 2; 28(4): 547-556.e3.

21. Shan R, Sarkar S, Martin S. Digital health technology and mobile devices for the management of diabetes mellitus: state of the art. Diabetologia. 2019 Mar 13; 62: 877-887.

22. Diabetes Australia. Continuous glucose monitoring [Internet]. Canberra: Diabetes Australia; 2021 [cited 12 Dec 2021], Available from: https://www.diabetesaustralia.com.au/living-with-diabetes/managing-your-diabetes/diabetes-technology/continuous-glucose-monitoring/

23. Diabetes Australia. Flash glucose monitoring [Internet]. Canberra: Diabetes Australia; 2021 [cited 10 Dec 2021]. Available from: https://www.diabetesaustralia.com.au/living-with-diabetes/managing-your-diabetes/diabetes-technology/flash-glucose-monitoring/

24. Beck RW, Bergenstal RM, Laffet LM, Pickup JC. Advances in technology for management of type 1 diabetes. Lancet. 2019 Sep 15; 394(10205): 1265-1273.

25. Juvenile Diabetes Research Foundation Continuous Glucose Monitoring Study Group, Beck RW, Hirsch IB, Laffel L, Tamborlane WV, Bode BW, Buckingham B, et al. The effect of continuous glucose monitoring in well-controlled type 1 diabetes. Diabetes Care. 2009 Aug; 32(8): 1378-83.

26. Fagherazzi G, Ravaud P. Digital diabetes: Perspectives for diabetes prevention, management and research. Diabetes Metab J. 2018 Sep 19; 45(4): 322-329.

27. Cahn A, Akirov A, Raz I. Digital health technology and diabetes management. J Diabetes. 2017 Sep 5; 10(1): 10-17.

28. Rice D, Nijs J, Kosek E, Wideman T, Hasenbring MI, Koltyn K, et al. Exercise-Induced Hypoalgesia in Pain-Free and Chronic Pain Populations: State of the Art and Future Directions. J Pain. 2019 Nov; 20(11): 1249-1266.

29. He D, Botta M, Kumar A. Low back pain: Two insights on treatment patterns from a patient journey analysis [Internet]. McKinsey & Company; 2017 Nov 1 [cited 21 Dec 2021]. Available from: https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/low-back-pain-two-insights-on-treatment-patterns-from-a-patient-journey-analysis

30. Healthdirect. Chronic pain [Internet]. Healthdirect; 2021 Jan [cited 28 Dec 2021]. Available from: https://www.healthdirect.gov.au/chronic-pain

31. New South Wales Government Health. Chronic pain management [Internet]. 2021 Mar 23 [cited 21 Dec 2021]. Available from: https://www.health.nsw.gov.au/pharmaceutical/doctors/Pages/chronic-pain-medical-practitioners.aspx

32. Schwan J, Sclafani J, Tawfik VL. Chronic Pain Management in the Elderly. Anesthesiol Clin. 2019 Sep; 37(3): 547-560.

33. Hayden JA, van Tulder MW, Malmivaara A, Koes BW. Exercise therapy for treatment of non-specific low back pain. Cochrane Database Syst Rev. 2005 Jul 20; Issue 3: Article no. CD000335.

34. van Middelkoop M, Rubinstein SM, Verhagen AP, Ostelo RW, Koes BW, van Tulder MW. Exercise therapy for chronic nonspecific low-back pain. Best Pract Res Clin Rheumatol. 2010 Apr; 24(2): 193-204.

35. Gross AR, Paquin JP, Dupont G, Blanchette S, Lalonde P, Cristie T, et al. Exercises for mechanical neck disorders: A Cochrane review update. Man Ther. 2016 Aug; 24: 25-45.

36. Boldt I, Eriks-Hoogland I, Brinkhof MW, de Bie R, Joggi D, von Elm E. Non-pharmacological interventions for chronic pain in people with spinal cord injury. Cochrane Database Syst Rev. 2014 Nov 28; Issue 11: Article no. CD009177.

37. Dixit S, Maiya A, Shastry B. Effect of aerobic exercise on quality of life in population with diabetic peripheral neuropathy in type 2 diabetes: a single blind, randomized controlled trial. Qual Life Res. 2014 Jun; 23(5):1629-1640.

38. Suh JH, Kim H, Jung GP, Ko JY, Ryu JS. The effect of lumbar stabilization and walking exercises on chronic low back pain: A randomized controlled trial. Medicine (Baltimore). 2019 Jun; 98(26): Article no. e16173.

39. Jack K, McLean SM, Moffett JK, Gardiner E. Barriers to treatment adherence in physiotherapy outpatient clinics: a systematic review. Man Ther. 2010 Jun; 15(3): 220-228.

40. Asar A. How AI and Technology Can Help Patients Manage Chronic Pain [Internet]. Forbes; 2020 Sep 25 [cited 21 Dec 2021]. Available from: https://www.forbes.com/sites/forbestechcouncil/2020/09/25/how-ai-and-technology-can-help-patients-manage-chronic-pain/?sh=1caf5e124489

41. Ledel Solem IK, Varsi C, Eide H, Kristjansdottir OB, Mirkovic J, Børøsund E, et al. Patients' Needs and Requirements for eHealth Pain Management Interventions: Qualitative Study. J Med Internet Res 2019; 21(4): Article no. e13205

42. Bostrøm K, Børøsund E, Varsi C, Eide H, Flakk Nordang E, Schreurs KM, et al. Digital Self-Management in Support of Patients Living With Chronic Pain: Feasibility Pilot Study. JMIR Form Res. 2020 Oct 23; 4(10): Article no. e23893.

43. Waldrop R, Cheng J, Devin C, McGirt M, Fehlings M, Berven S. The Burden of Spinal Disorders in the Elderly. Neurosurgery. 2015 Oct 1; 77(Issue suppl_1): S46-S50

44. Druss BG, Marcus SC, Olfson M, Pincus HA. The most expensive medical conditions in America. Health Aff (Millwood). 2002 Jul-Aug; 21(4): 105-11.

45. Hoy D, March L, Brooks P, Blyth F, Woolf A, Bain C, et al. The global burden of low back pain: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis. 2014 Jun;73(6):968-974.

46. Sivanesan E. Spinal Cord Stimulator [Internet]. Baltimore: John Hopkins Medicine; n.d. [cited 4 Jan 2022]. Available from: https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/treating-pain-with-spinal-cord-stimulators

47. Cleveland Clinic. Closed Loop Spinal Cord Stimulation Proving More Effective at Relieving Pain [Internet]. Cleveland: Cleveland Clinic; 2018 Jul 26 [cited 4 Jan 2022]. Available from: https://consultqd.clevelandclinic.org/closed-loop-spinal-cord-stimulation-proving-more-effective-at-relieving-pain/

48. Dydyk AM, Tadi P. Spinal Cord Stimulator Implant. 2021 Sep 29. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan–. Available from: https://www-ncbi-nlm-nih-gov.ezproxy.utas.edu.au/books/NBK555994/

49. Mekhail N, Levy RM, Deer TR, Kapural L, Li S, Amirdelfan K, et al. Long-term safety and efficacy of closed-loop spinal cord stimulation to treat chronic back and leg pain (Evoke): a double-blind, randomised, controlled trial. Lancet Neurol. 2020 Feb;19(2):123-134.

50. Maheshwari A, Pope JE, Deer TR, Falowski S. Advanced methods of spinal stimulation in the treatment of chronic pain: pulse trains, waveforms, frequencies, targets, and feedback loops. Expert Rev Med Devices. 2019 Feb;16(2):95-106.

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