Soft-Bioelectronics to Detect Neuromotor Disorders in Infants

Image Credit: Pixabay

By Swetha Vaidyanathan

Visualize the gradual flowering of a dancer's body into movements coordinating the eyes, arms, and torso. Beyond these visual fluidic movements, what happens inside the brain while such movements are carried out is intriguing. Mingled with this thought is a sense of wonder: how does the brain neuro-muscularly coordinate these movements? Going back to infancy, do movements exhibited by babies impact their neural pathways? If so, does that show any information regarding neurological deficits or help track neuromotor development?

These are the questions researchers Prof. Zhenan Bao, and Yasser Khan addressed in their commentary published in November 2021 regarding work done at Northwestern University in Prof. John Roger's group. Current approaches for assessing the neurological issues for infant movements involve quantitative and qualitative monitoring using systems equipped with motion tracking, electromyography, and video motion capture. Current methods are cumbersome due to the size and weight of the heavy wired hardware and is constrained to be used only in specialized facilities. The development of bioelectronics, including wireless sensors that are flexible, soft, and low-cost may enable clinicians to conduct remote assessments and in-home evaluations of movement patterns in infants that may indicate neurological conditions.

The central nervous system, consisting of the brain, the spinal cord, and the network of nerves throughout the body is responsible for coordinating body movements. These complex and spontaneous movements, often referred to as General Movements (GM) in infants, are observed from the early fetal stage to the first half-year of life. Therefore, assessing atypical GM behaviors in infants could reveal valuable information regarding their developing central nervous system, thereby revealing details of neuromotor pathologies that presage clinical conditions very early on. Such an approach would enable prompt intervention, which could limit disability, enhance recovery, and lower lifetime costs.

For example, the use of Prechtel's assessment (a widely used tool for assessing the nervous system) on infants' GMs (10 to 20 weeks) shows predictions of later cerebral palsy in kids at their three years of age. The predictions are carried out based on the nature and the frequency of occurrence of the different types of GM. Prior studies reveal that there are three types of GMs, writhing, fidgeting, and goal-oriented movements that include reaching and grasping.

Prechtel assessment specifically shows two atypical GMs associated with cerebral palsy. The first consistent pattern includes an abnormal type of writhing, called the Cramped, synchronous GM, which are rigid movements that lack smoothness and fluency. The second atypical pattern is a dearth of fidgety-type GMs.

These results show 97% sensitivity and 89% specificity in predicting later cerebral palsy. Though this assessment is not invasive nor resource-intensive compared to traditional methods, the technique is subjective and depends heavily on high-quality video monitoring and access to clinical records and medical experts. This limitation may hinder its scalability to remote locations making such facilities inaccessible to an extensive population.

A Soft-Electronic, Wireless Sensor Network

Addressing the above causes, the authors have elaborated on the findings from a companion article, based on a similar problem statement, published in PNAS by Jeong et al(1). The research paper demonstrates an Artificial Intelligence (AI) based soft-electronic, wireless sensor network that can digitize movement behaviors and vital signs in infants, thereby enabling rapid and routine motor evaluations.

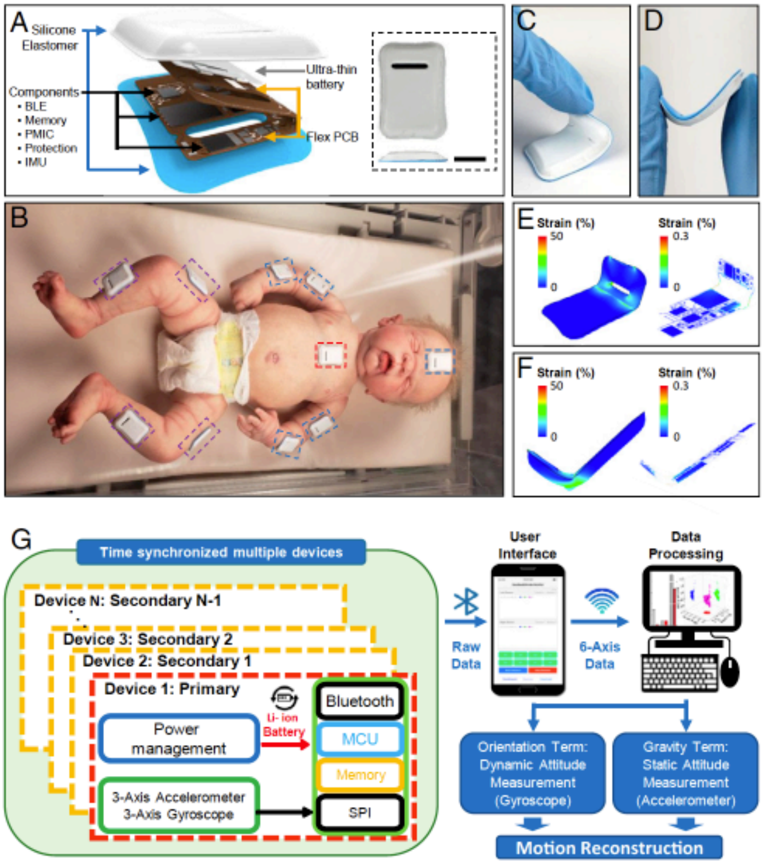

Fig. 1. Images, schematic illustrations, and functional flow charts for miniaturized wireless sensors (i.e., CORB sensors) designed for quantifying gross motor behaviors and vital signs in infants. (*A*) Exploded-view schematic illustration of the device. Optical image of the device (*Inset*). (Scale bar, 1 cm.) (*B*) Measurement configuration for capturing full body motions, illustrated with a baby doll. (*C*–*F*) Images and finite element analysis computations of a device flexibility during various mechanical deformations: peeling (*C* and *E*) and bending with an angle of 90° (*D* and *F*). (*G*) Functional diagram of the platform showing hardware blocks including the power management, Bluetooth radio, microcontroller, memory, and six-axis inertial measurement unit for each device. The collected data from each device include synchronized timestamps to ensure millisecond relative timing accuracy. A user interface on a smartphone or table controls the devices, captures real-time data, and supports data downloads a 3D motion reconstruction using a local PC.

The system, encapsulated in a thin silicone elastomer, consists of flexible inertial sensor nodes that send synchronized timestamps and movement information. When the sensor node is placed at strategic locations on the body of an infant and operated in a wide bandwidth, they can capture their continuous, full-body kinematics. These data allow full-body motion reconstruction in static and dynamic orientations relative to the direction of gravity. Further, operating in such a time-synchronized fashion, ten sensor nodes record data from a three-axis digital accelerometer and a gyroscope. The data could then be used to decode information regarding acceleration, angular velocity, and normalized activity levels.

These quantitative measurements can also be analyzed with machine learning techniques to show atypical GMs, such as trouble in lifting and holding up the head and complete stiffness in the limbs with few or no movements. Features that otherwise would remain hidden in the video analysis could be easily spotted from the data sets.

A Promising Future

Given that the solution is low-cost, easy-to-use, and deployed to hospitals, the authors speculate that the soft sensor networks are promising for use with infants to monitor the hidden clues in GMs for cerebral palsy. By scaling the study to a larger population set, the authors envision similar adaptable methods will enable remote detection of neurological disorders before conventional clinical identification.

Capturing a broad range of vital signs information would enable general health monitoring beyond capturing movement behaviors. The analysis of collected data would open up new ventures in machine learning applications for creating databases to compare with traditional assessments.

Source article:
Khan Y, Bao Z. A soft-electronic sensor network tracks neuromotor development in infants. Proc Natl Acad Sci U S A. 2021 Nov 16;118(46):e2116943118. doi: 10.1073/pnas.2116943118.
https://viterbi-web.usc.edu/~yasserkh/assets/files/khan2021soft.pdf

Companion article:
(1): Jeong H, et, al. Miniaturized wireless, skin-integrated sensor networks for quantifying full-body movement behaviors and vital signs in infants. Proc Natl Acad Sci U S A. 2021 Oct 26;118(43):e2104925118. doi: 10.1073/pnas.2104925118. PMC8639372.
https://www.pnas.org/doi/abs/10.1073/pnas.2104925118

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