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Could Wearables Protect Youth and Children on Farms?

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The hazards for injury and death in agricultural settings are widely known, as are the risks that disproportionately affect children. Reputable data suggest one American child dies in an agriculture-related incident about every 3 days[1] and another 50 suffer injuries serious enough to require an emergency room visit daily.[2] Further, documented youth agricultural worker fatalities have exceeded those in all other industries combined for over a decade, with teenagers aged 15–17 making up 81% of all occupational fatalities.[3]

The most prominent traditional strategies to protect safety of children and young workers in agricultural settings are supervision (adults carefully watch children and young workers) and separation (children kept away from dangerous environments like animal pens, machinery, pools, and grain storage areas by physical fences/barriers; youth workers kept away from tasks they are not trained to engage in safely). Although effective when properly implemented, these strategies have had minimal impact on lowering injury risks or rates, largely due to challenges of consistently and reliably implementing and enforcing the strategies.

We propose use of wearable technology as an alternative. Use of technology that automates separation of children and youth from dangerous agricultural risks may be more effective than reliance on human behavior. As a familiar example, suburban dogs are "fenced" with electronic systems that shock them if they try to escape the perimeter. We'd never dream of rigging such a system that shocked our children, but could wearable technology offer a comparable solution that reliably and consistently separates young children from risks in the agricultural environment?

A Google Scholar search with keywords ((wearable* or beacon* or Bluetooth*) and (child* or teen* or adolescent) and (farm or agriculture) and (safety or injur* or accident*)) yields no relevant empirical research. There is substantial discussion concerning use of wireless sensors to monitor crops, soil conditions, weather conditions, livestock behavior and locations, and conduct of smart or precision agriculture.[4–6] There also is scattered mention of using technology to monitor worker locations, or to monitor safety of worker environments (e.g., to detect dangerous gases in manure storage areas).[4] In related research, technology can be used for parents to track their children's locations.[7–9] However, efforts to use the technology to protect child and youth safety on the farm appear absent in the published literature.

Today's technology allows us to leverage Bluetooth Low Energy (BLE) Beacon technology to increase safety in farm environments. Conceptually, such an application of wearable technology would consist of two components, a wearable beacon device and a sensor/detector with cutoff switch:

(1) Wearable beacon device. The child/youth user wears a device that communicates with a receiving device in the environment. The wearable device might be a watch, bracelet, necklace, or anklet. It could also be attached to or sewed into the youth's clothing. These devices are small; BLE beacons can be as small as a coin, making them ideal

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to use as wearable devices. They function by constantly emitting an omnidirectional wireless signal along with an identifier that can be programmed into the beacon.

(2) Sensor/detector with cutoff switch. Agricultural settings with risks present would be rigged with sensors or detectors that run constantly, detecting Bluetooth beacon signals from the wearable devices. By calculating the Received Signal Strength Indicator (RSSI) value of the beacon's signal, the detector can immediately calculate how close the person wearing the device is to the detector and then react as programmed.

Using this system, we envision two types of approaches to improve safety. A time-critical hazard would require immediate action (that is, within a few seconds) to prevent injury; we label this *the "reactive" method*. Contrarily, a non-time critical hazard would require prompt action, but could notify responsible adults to act in a somewhat longer time window; we call this *the "alert" method*.

(1) *Reactive method*. In the reactive method, immediate and automated actions are required to ensure safety. For example, a toddler might be approaching a moving tractor or ATV, two of the most common causes of fatal youth injuries in agricultural settings.[10,11] In such a scenario, it is urgent to shut off the vehicle to ensure safety. The system could be automated to take immediate preventive action by pairing the detector with a "kill switch," a circuit that cuts off the engine immediately. The same approach could be used with farm machinery. If a teen worker untrained in using a power take-off (PTO) shaft approached that machinery while wearing a beacon, the machinery could be programmed to detect the risk and automatically shut off (override systems would be present in case of emergency). A major advantage of the reactive method is that existing farm equipment can easily be retrofitted with this system by adding the detector and cut-off "kill switch" with minimal modifications.

(2) *Alert method*. The alert method provides information to avert injury quickly, but not immediately. In this system, the goal is to alert a responsible adult or supervisor when youth approach a risky area too closely. With young children, this might be used near manure pits, active worksites, livestock ponds, or large animal enclosures. With youth workers, it might be used near dangerous machinery the youth has not yet been trained to use. When the child or youth wearing a beacon approaches the hazard zone, detectors placed in the hazard zone will identify the situation by sensing an increasingly stronger RSSI from the beacon. When the detector identifies such a situation, it would signal a responsible adult through text, phone call, or alarm. The adult could then respond appropriately. The alert method could also be used in the opposite direction, to identify when a child leaves a safe area rather than when they enter a risky area. For example, safe outdoor play areas for toddlers might be equipped with detectors that identify when a young child wanders away from the safe fenced area.

Critics might cite at least five concerns. First, why are Bluetooth beacons and wearables required? Why not use GPS instead? The response involves at least three reasons. First, GPS has less accuracy at small distances that are critical for safety. Being within 100 yards of an irrigation pond might be fine for a 5-year-old, but being within 10 yards creates risk. BLE beacons offer excellent accuracy with signals transmitting up to 100 meters. Second, GPS may not work in indoor settings such as barns or greenhouses, or in areas shaded by trees such as orchards. Third, internet connectivity might be limited in remote farm areas. Bluetooth beacons function anyplace, have no interference from radio or other waves, and fail to sense only when batteries fail. Alternatively, why not use RFID? We cite three reasons: (a) most RFID tags have greatly limited range, of up to only 6 feet or so; (b) BLE beacons have better location granularity to accurately estimate location than RFID tags; and (c) detecting BLE beacon signals requires no special hardware, whereas RFID detection requires specialized readers.

Second, critics might also worry about durability and sustainability. Our research in an urban street environment has demonstrated Bluetooth beacons to be durable for long-term use in outdoor settings.[12,13] Batteries last from 12 to 24 months and can be easily and rapidly replaced. BLE Beacons are also inexpensive – for example, Estimote beacons retail for US$25–30.

Third, critics may argue that parents still must take action to install and use Bluetooth beacon and wearables, or employers must do the same with potentially resistant workers. We respond in a few ways. First, wearables could be manufactured to be appealing to children (e.g., with appealing cartoon or superhero character themes), easing the parents' task to convince children to wear them. For youth workers, they could be embedded in other work gear, such as uniforms or hats. Second, scientific injury prevention literature clearly states the advantages of more passive injury prevention strategies, which function on their own once installed, over more active strategies which require active engagement by a person.[14] Wearables do require set-up and then assurance children/youth wear the devices. But it is far more passive than active and constant supervision, which we know fails often. More passive intervention through wearables is likely to be more effective.

Fourth, there may be concerns over data security. These are alleviated because no data would actually be stored. BLE beacons have no storage capacity and emit unidirectionally to wearables which would typically contain no storage either. Thus, in most applications, no data would be stored anywhere. Last, there may be concern that possession of wearables will lead to a false sense of security and safety by parents or supervisors, and a failure by the technology or user could result in catastrophe. We acknowledge this risk, but maintain some use is better than none, technological failures can be signaled (e.g., low battery alarms similar to those on home smoke detectors), and legal liabilities could be addressed.

Is all this. the stuff of futuristic science fiction that might be reality in decades but not now? We emphatically argue, "no". It is the stuff of today, ready for immediate pilot implementation. In fact, wearables have been successfully piloted in other occupational settings, such as health and body temperature monitoring among military personnel[15] and detection of heat stress among construction workers.[16] Others have proposed their use to manage logistics of workers and forklifts in industrial settings.[17] Bluetooth beacons also are used successfully in other safety applications, including our own work using BLE beacons to signal distracted pedestrians as they approach a street-crossing[12,13] and in disaster management.[18]

In summary, widespread dissemination of wearables to protect safety in agricultural settings may be premature, but controlled empirical study of efficacy is ripe for initiation. With evidence of pilot success, broad dissemination could reduce injuries and deaths in agricultural work settings not just among children and youth but among all workers.

Serious public health problems require innovation and "thinking big". Use of wearable technology to prevent injuries on farms has challenges, but those challenges can be overcome with contemporary technology. Sitting idle will do nothing; taking action could save lives.

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