

Simplifying Hydration Monitoring: Wearable Sensor for Accessible Dehydration Detection in Vulnerable Populations

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Abstract— Dehydration is a common but often underestimated health concern, especially among the elderly, who often lose their perception of thirst. Current hydration monitoring technologies are typically complex, intrusive, or dependent on external devices such as smartphones, limiting their suitability for older individuals. In this study, we developed a wearable, noninvasive, standalone device to detect hydration status. Utilizing a Galvanic Skin Response (GSR) sensor, the device measures change in skin conductivity correlated with hydration levels. The Arduino Nano processes sensor data and provides immediate feedback via one of three methods, LED, buzzer, or vibration, according to user preference. Its simplicity, low cost, and independence from external devices make this solution especially accessible and practical for elderly users.

Keywords— dehydration; GSR sensor; wearable device; Arduino Nano

I. INTRODUCTION

Dehydration is a widespread health issue that profoundly impacts both mental and physical well-being, impacting organ function, nutrient transport, and body temperature regulation [1]. Even mild dehydration (1–2% fluid loss) affects memory, focus, and reaction time, while severe cases may lead to heatstroke or kidney failure. Vulnerable populations, such as athletes, outdoor workers, and the elderly, are more susceptible, and often fail to recognize symptoms until they have progressed [2]. Consequently, early detection and real-time hydration monitoring are more than beneficial, they are essential for effective health management [3].

Current hydration tracking relies on self-assessment or reminders, both of which are unreliable [4]. Although advanced systems utilizing Bluetooth, blood tests or urine analysis offer greater precision, they are generally complex, invasive and dependent on external devices such as smartphones, which severely limit their practical applicability, especially for older individuals [4]. There is therefore an urgent need for a simpler, more accessible and non-invasive solution for real-time hydration monitoring.

To address this gap, we propose a wearable hydration sensor integrating skin moisture detection through GSR. In this

system, an Arduino Nano processes data and provides immediate feedback in the form of customizable LED, buzzer or vibration alerts. The device is standalone, battery-powered, and requires no apps or wireless connectivity. This study focuses on efficient hardware integration, sensor calibration, and firmware optimization to deliver a reliable and user-friendly product. It aims to reduce dehydration risks and promote hydration habits, especially among elderly users or those in high-heat environments.

As well as reducing the risks of dehydration and fostering better hydration habits, particularly among the elderly and those in high heat environments, this innovative project also aligns with five UN Sustainable Development Goals (SDGs). The five goals are: Goal 3: Good Health and Well-being by enabling real-time health monitoring; Goal 7: Affordable and Clean Energy through its low-power, standalone design; Goal 8: Decent Work and Economic Growth by enhancing safety and productivity for outdoor workers; Goal 9: Industry, Innovation, and Infrastructure by presenting a scalable and innovative health technology solution; and Goal 13: Climate Action by contributing to resilience against heat-related physiological stress.

II. PROBLEM STATEMENT

Dehydration is a serious health concern that can cause fatigue, headaches, dizziness, confusion, muscle cramps, and decreased cognitive and physical performance. In severe circumstances, it may result in heat exhaustion, kidney damage, or even life-threatening conditions such as heatstroke. Athletes, outdoor laborers, and elderly individuals are at higher risk, as they may not recognize the symptoms until they become serious [5]. Despite these risks, current hydration monitoring methods remain inadequate, often relying on subjective self-assessment or irregular reminders, both of which are prone to errors.

The lack of a simple, real-time, and non-invasive hydration monitoring solution leaves individuals vulnerable to dehydration-related health complications. This highlights the pressing need for a more effective and accessible means to manage hydration levels.

III. LITERATURE REVIEW

Monitoring hydration status has become an increasingly relevant research area due to its importance in maintaining health and preventing dehydration-related complications. The literature reports various wearable systems, each aiming to track hydration through various physiological signals or behaviors. However, most of these are either too invasive, dependent on smartphones, or unsuitable for elderly users who require simplicity and autonomy.

AutoHydrate, a wearable system combining a smartwatch and throat microphone to recognize drinking behavior, was introduced in [6]. The system achieved high accuracy (91.5%) but had the drawbacks of relying on Bluetooth communication with a smartphone, and requiring user interaction, reducing its practicality for elderly use.

Another system consisted of smartwatch-compatible device that used galvanic skin response (GSR) and photoplethysmography (PPG) sensors to estimate hydration based on sweat analysis, developed in [7]. Although accurate, the device required smartphone connectivity and complex signal processing. An RF-based wristband that detected hydration levels by measuring variations in signal strength (RSSI) was explored in [8]. However, its requirement for environmental calibration made it impractical for casual or daily use. A thermal-sensing device that evaluated urine temperature using infrared sensors was proposed in [9]. Its accuracy was offset by its dependence on urine sample collection limits its use in real-time, wearable applications.

A multi-sensor system involving a smart mouthguard and chest patch for comprehensive hydration and vital sign monitoring was presented in [10]. This technologically advanced solution, however, is highly complex, expensive, and relies on smartphone-based data processing.

Table 1. Comparison of existing hydration monitoring systems and the proposed device

Study	Technology Used	Limitations	Proposed Device Advantage
Auto Hydrate [6]	Throat microphone, smartwatch	Needs phone, not standalone	Fully autonomous; no connectivity required
SpectroPhon-DBM [7]	GSR + PPG	Needs phone, signal processing	Simple GSR only; low-cost system
BioMindR RF Band [8]	RF signal strength (RSSI)	Sensitive to environment	No calibration needed

Thermal Urinalysis Device [9]	IR sensor urine temperature measurement	Requires urine sample	Continuous, wearable without samples
Mouthguard + Chest Patch System [10]	Mouth + chest multi-sensor	Expensive; requires multiple wearables	Single wrist device with intuitive alerts
Our Wearable Dehydration Sensor Device	GSR sensor + Arduino Nano + LED, buzzer, vibration	GSR affected by external factors like humidity and stress	Standalone, low-cost, non-invasive, customizable alerts

Compared to previous systems, the proposed device offers a unique combination of simplicity, autonomy, and accessibility. It operates fully independently, without the need for smartphones, Bluetooth, or external data platforms, which enhances usability, particularly for elderly users. Relying solely on a GSR sensor and a straightforward microcontroller, the low-cost and energy-efficient system provides real-time hydration alerts through multiple customizable feedback options. This design approach addresses the key limitations of existing solutions and makes the device suitable for daily use in real-world scenarios.

IV. METHODOLOGY

This section details the components and steps needed for constructing our wearable dehydration alert system, aiming for real-time, non-invasive hydration detection using low-cost electronics.

4.1 Sensor Selection and Justification

The device uses a GSR sensor to monitor skin conductance, which reflects sweat gland activity and moisture levels. When skin is dehydrated, conductivity drops, enabling GSR to serve as a non-invasive proxy for hydration. The sensor was chosen for its simplicity, affordability, low power needs, and Arduino compatibility.

However, accuracy can be affected by factors such as temperature, humidity, stress, and skin type [11]. Studies such as [6] show that pairing GSR with deep learning improves classification of hydration states with up to 97% accuracy. GSR therefore offers effective early warnings, although it is not medically diagnostic. Future versions may integrate additional biosensors (e.g., temperature or PPG) and machine learning for better accuracy and personalization.

4.2 System Components

The key components are a GSR sensor, Arduino Nano, LED, buzzer, vibration motor, and three buttons for alert modes.



The device is breadboard-based and powered by a 9V battery.

4.3 Circuit Integration

The GSR sensor connects to Arduino's analog pin (e.g., A0) and is sampled periodically [12]. However, it is important to note that certain factors, such as temperature, humidity, stress, and skin type can affect accuracy. If readings fall below threshold, the chosen alert (LED, buzzer, or vibration) is activated. Debounce delays prevent repeated triggers.

4.4 Power Management

A 9V battery supplies power via Arduino's voltage regulator. All parts are optimized for low energy consumption.

4.5 Future Extension Possibilities

Potential improvements to the system include a more compact PCB design, added SMT components, and a Li-Po battery for better portability. A flexible, waterproof wristband and 3D-printed casing can enhance wearability.

Software-wise, AI could be used to personalize hydration alerts and reduce false positives. Users with disabilities could be supported with accessibility features like haptic/voice output or app sync. Additionally, data logging via SD or BLE could enable remote monitoring and long-term trend analysis.

V. RESULTS AND DISCUSSION

This section outlines the results obtained from the implementation and testing of the wearable dehydration monitoring prototype. Findings are presented with respect to hardware performance, the responsiveness of the alert mechanisms, and a comparative assessment against previously proposed hydration monitoring systems.

5.1. Functional Prototype

The wearable dehydration alert system was successfully assembled using low-cost, commercially available components. The prototype includes an Arduino Nano connected to a GSR sensor and three output devices: a red LED, a buzzer, and a vibration motor [13]. The circuit was mounted on a breadboard and powered by a 9V battery.

Users can select their preferred alert mode by selecting one of three pushbuttons. The selected output module is triggered once the GSR sensor detects a conductivity value below a predefined threshold. This modular setup ensures clear, immediate feedback in various real-world scenarios. The design facilitated switching between visual, auditory, and tactile alerts.

5.2. Observations and Performance

During testing, the device continuously measured skin conductance and compared values against the static threshold. When dehydration was simulated (e.g., using dry fingers or by reducing skin moisture), the sensor readings dropped, activating the corresponding feedback mechanism (LED, buzzer, or vibration motor). The observed GSR values typically ranged between 580–650 under normal skin conditions, falling to below 400 with a decrease in skin moisture. The system performed reliably in indoor environments and was easy to operate. A 5-second interval was implemented to reset the alert cycle and minimize false or repeated warnings.

5.3. Practical and Scientific Implications

The results of this study demonstrate that a simple GSR-based sensor, when integrated with a low-cost microcontroller, can provide a functional and accessible method for estimating hydration status in real time. Although not able to provide clinically diagnostic precision, GSR is effective in detecting relative changes in skin moisture that correspond to early signs of dehydration [14].

From a practical standpoint, the device offers a significant advantage for users, particularly the elderly, by eliminating the need for smartphones, wireless connectivity, or complex interfaces. The selectable alert modes (LED, buzzer, vibration) enhance accessibility and allow users to choose their preferred feedback method based on personal needs or sensory limitations.

Scientifically, the system shows that basic physiological signals, such as skin conductance, can be utilized for health monitoring, avoiding complexity and cost associated with more advanced wearable technologies. While more sophisticated systems using multiple sensors or cloud-based analytics may offer higher accuracy, the trade-off in simplicity and independence often renders them unsuitable for elderly or vulnerable users. Balancing technical feasibility with usability, our system is an effective tool for promoting hydration awareness and for reducing dehydration-related health risks in daily life.

5.4. Factors That Influence Results

Five factors can affect the accuracy of GSR-based hydration detection. First, environmental conditions such as ambient temperature and humidity may influence skin moisture levels, leading to false alerts in extremely dry or cold settings. Secondly, baseline variability can also result from user-specific physiological differences, including skin type and sweat gland activity. Thirdly, poor sensor contacts or motion during use may introduce noise into the measurements. Fourth, the system uses a fixed threshold and a 5-second reset interval, which helps reduce repeated alerts; however, this may limit sensitivity to short-term hydration changes. Finally, the prototype does not perform personalized



calibration, therefore, it may not fully adapt to individual differences without further development.

5.5. Institutional Support and Applicability

In conclusion, the developed prototype demonstrates that a low-cost, non-invasive, and standalone dehydration monitoring device is both feasible and functional. Designed with elderly users in mind, the system successfully detects skin conductance changes associated with dehydration and provides immediate feedback through customizable alert modes. It is suitable for daily use due to its simplicity, portability, and independence from smartphones.

The current prototype is based on basic components and breadboard assembly, and its usability and reliability could be improved in areas such as sensor integration, ergonomic design, and data logging. Given the absence of government-supported dehydration monitoring tools in Turkey, this study also holds potential for institutional support and public health funding. With proper certification and clinical validation, the device could contribute to improved hydration awareness and reduced dehydration-related health risks in vulnerable populations.

VI. CONCLUSION

This study successfully demonstrated the feasibility of a standalone, non-invasive, and user-friendly wearable device for dehydration monitoring, particularly suited for elderly individuals. Using a GSR sensor and an Arduino Nano, the system detects changes in skin conductance and allows users to select alerts through LED, buzzer, or vibration modes.

Despite limitations in hardware resources and development time, the prototype performed reliably in indoor testing scenarios. The system can evolve into a viable product for real-world use with improvements such as miniaturization, multi-sensor integration, and data storage. Its simplicity, low cost, and accessibility make it a strong candidate for public health applications and potential institutional support.

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