Received: 30 December 2021 | Accepted: 17 February 2022

DOI: 10.1111/acer.14794

ALCOHOLISM CLINICAL & EXPERIMENTAL RESEARCH

COMMENTARY

Examining features of transdermal alcohol biosensor readings: A promising approach with implications for research and intervention

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Funding information
This work was supported by NIH grants R21AA027191, P01AA029547, P01AA029543, R01AA013746, and K01MH098798.

Russell et al. (2022) study integrating smartphone and wearable alcohol biosensor technology to measure real-world drinking behavior and related consequences is a timely and important contribution to the alcohol research field. Most wearable alcohol biosensors detect alcohol use by measuring the small amount (~1%) of consumed alcohol that is present in the skin via sweat or diffusion (Swift, 1993). While these devices have been described in the alcohol literature for over 20 years (Wang et al., 2019), to date, transdermal alcohol biosensors have been used primarily as an objective indicator of the binary outcome of alcohol drinking versus abstinence (e.g., Barnett et al., 2014), and more quantitative applications of alcohol biosensor readings have been limited due to the challenges in estimating breath or blood alcohol concentration (BrAC/BAC) from transdermal alcohol concentration (TAC; Hill-Kapturczak et al., 2015; Luczak & Rosen, 2014). Despite recent advances in this area, such as applying machine learning algorithms to TAC data to identify drinking events and estimate BrAC/BAC (Fairbairn et al., 2020), this process is complicated by the potential influences of multiple individual differences and environmental factors, including skin thickness, alcohol metabolism, gender, and ambient temperature and humidity at the time of recording (Wang et al., 2019). To date, the complex nature of the TAC-to-estimated BrAC/BAC conversion process remains a barrier to wider application of transdermal alcohol biosensors. In their paper, Russell et al. (2022) adopted a different approach: rather than attempting to estimate BrAC/BAC from TAC, they instead extracted five previously identified features of the TAC signal during real-world drinking events and examined the associations between those features and alcohol use and drinking-related consequences. Their work represents an intriguing and novel "blueprint" for future analyses of alcohol biosensor data and suggests that TAC data may have significant value to the alcohol research field beyond its utility as a proxy measure of BrAC/BAC.

In their study of young adult heavy drinkers, Russell et al. (2022) used smartphone-based ecological momentary assessment (EMA) to capture self-reported alcohol use via both scheduled and user-initiated (episodic) prompts over a 5-day study period. Scheduled "morning after" EMA prompts assessed participants' recollections of both the number of standard alcoholic drinks consumed and drinking-related consequences experienced during the prior drinking episode, while user-initiated EMA prompts collected drinking-related outcomes as the drinking events occurred. Participants wore an alcohol biosensor (Secure Continuous Remote Alcohol Monitoring-Continuous Alcohol Monitor anklet; SCRAM-CAM) to provide a continuous measure of TAC over the entire study period. The authors extracted five features from each study day's TAC signal: the maximum value recorded each day (i.e., peak TAC), area under the daily TAC curve (AUC), rise rate, fall rate, and duration. Greater values of peak TAC indicate greater intoxication, while AUC provides a single index reflecting both the intensity and length of the drinking event. Rise and fall rates indicate the speed of intoxication (absorption) and elimination of alcohol from the body, respectively, and duration reflects the amount of time the person

spent exposed to alcohol (i.e., where TAC > 0). Briefly, the findings indicated significant within-participant correlations between TAC features and self-reported drinking, with stronger associations between TAC features and drink counts derived from morning (*r*s 0.60 to 0.74) versus episodic EMA (*r*s 0.30 to 0.50). Considering each TAC feature individually, AUC had the strongest association with both morning report ($r = 0.73$) and episodic EMA ($r = 0.50$) drink counts. Between-participant correlation analyses produced similar patterns of results. Importantly, AUC, peak TAC, and rise rate significantly predicted alcohol-related consequences within individuals—even after adjusting for morning-reported or EMA drink totals—with AUC and peak TAC being the most consistent predictors of commonly reported alcohol consequences (e.g., hangover, arguments, blacking out). Encouragingly, overall compliance with the study procedure was high, with 94% of scheduled EMA prompts completed and minimal evidence of tampering with the SCRAM device, supporting the feasibility of deploying this mixed EMA/biosensor approach among young adult heavy drinkers in the field.

The paper by Russell and colleagues comes at an important time for the alcohol research field. Recent technological advances and new entries in the biosensor space have produced devices that are smaller, cheaper, and less burdensome to participants (Wang et al., 2021). At the same time, disruptions to laboratory research caused by the ongoing COVID-19 pandemic have generated strong interest in reliable, minimally intrusive, and inexpensive remote alcohol assessment tools. Data from Russell et al. (2022) support using TAC recorded via alcohol biosensors to characterize naturalistic drinking while minimizing participant burden. However, and perhaps more exciting than serving as a replacement for BrAC/BAC, EMA, or other self-recorded methods, their outcomes suggest that elements of the TAC curve can provide researchers with dissociable and potentially complementary quantitative information about drinking behaviors (e.g., pace, length, and magnitude of a drinking episode), and can predict alcohol-related consequences even when accounting for self-reported alcohol consumption during the event. Importantly, the data indicate that continuously measuring TAC can provide researchers with important insights into outcomes after individuals have stopped drinking, during descending TAC (approximately corresponding to the descending limb of the BrAC/BAC curve). The authors note that greater TAC fall rate was associated with increased risk for alcohol consequences—especially blacking out—in their sample. Exploring such associations in the context of naturalistic drinking events may require continuous objective alcohol monitoring as participants often fall asleep during the descending BAC limb and cannot complete self-report or breathalyzer assessments. Intriguingly, the authors propose that faster fall rates may indicate more rapid alcohol clearance, which could be a risk factor for AUD when combined with high levels of alcohol use. This hypothesis deserves additional investigation and highlights the advantage of TAC to record valuable data along the entirety of the BAC curve even several hours after participants have stopped drinking, including during sleep, when any active measure of BAC would not be possible.

Russell et al.'s (2022) findings also raise intriguing possibilities for the role of alcohol biosensors as intervention tools. These devices have been used for years in forensic settings to detect alcohol use in individuals who are court-mandated to avoid alcohol, such as DUI offenders, and have been shown to reduce recidivism in that group (Fell & Scolese, 2021). Transdermal sensors have also been investigated as adjuncts to alcohol treatment in nonforensic outpatient settings, where they may enhance outcomes by detecting unreported alcohol use and improving compliance with other interventions, such as contingency management (Alessi et al., 2019; Barnett et al., 2017). The results of the study by Russell et al. (2022) suggest that the value of transdermal sensors as treatment tools may extend beyond simply detecting drinking to identifying problematic patterns of alcohol use that are associated with greater risk of alcohol-related consequences. This could pave the way for the development of new just-in-time interventions. For instance, when paired with a smartphone application with the ability to collect and analyze TAC data, it is conceivable that an alcohol biosensor could detect a rapid escalation in TAC and deliver a personalized alert to the user. These reminders could be delivered in the form of a text message or in-app notification and offer reminders about drinking behavior (e.g., to slow down or stop drinking, or that the observed pattern of consumption is associated with a greater risk of hangover) or messages intended to enhance motivation for drinking-related goals (e.g., setting and adhering to a consumption limit). In addition, EMA and TAC data could be paired with personalized feedback on other risk factors for alcohol-related problems, such as subjective alcohol responses (Fridberg et al., 2015), to further enhance existing brief interventions for at-risk drinkers. Finally, the new generation of wrist-worn alcohol biosensors resembles a smartwatch or fitness tracker and are considerably smaller and less intrusive than older generation devices such as the SCRAM, which may translate to greater acceptability among the broader heavy drinking population (Wang et al., 2021). Given the popularity of wearable devices in general (e.g., Fitbit, Apple Watch), future intervention approaches could incorporate alcohol biosensors with other types of physiological monitoring (e.g., actigraphy) to examine the extent to which alcohol use interferes with sleep and other health-related outcomes. These data could then be presented as part of a personalized intervention that could help patients identify specific, relevant alcohol-related consequences (e.g., poor sleep quality, reduced physical activity), and enhance motivation to change drinking behavior.

While current data point to a bright future for alcohol biosensors as assessment and intervention tools, there are some limitations of this approach that should be addressed. First, alcohol researchers must endeavor to test and validate these devices in diverse samples of drinkers from across the alcohol use spectrum. To date, a great deal of experimental work with these devices has been conducted in young adult samples, and more research on applications of these devices in older, heavier drinking groups (including patients with AUD), and populations with chronic diseases that can be affected by alcohol use (e.g., persons with HIV; Richards et al., 2021) is needed. Importantly, at this time, TAC cannot be converted directly to an estimate of the volume of alcohol consumed, complicating its use as a between-participant indicator of alcohol use. We expect

this to be an area of further research and development in the field. Furthermore, the field should strive to establish a set of best practices for collecting and analyzing TAC data in clinical and nonclinical alcohol-using groups like that which exists for other areas of psychophysiological research, such as analyzing event-related potential data (Kappenman & Luck, 2016). Relatedly, it will be important to devise guidelines for enhancing participant compliance with alcohol biosensors given the importance of this factor in all potential research or clinical applications. In contrast to the SCRAM-CAM, new wrist-worn alcohol biosensors are designed to be easily removable and do not currently feature software designed to identify tampering or noncompliance, although compliance may be inferred to some extent from temperature and movement data recorded by those devices. This may limit the application of newer wrist-worn alcohol biosensors in certain contexts, such as clinical applications where reducing drinking is incentivized (e.g., contingency management interventions). Choosing the right alcohol biosensor will depend upon the individual clinical or research question, with different types of devices having different strengths and weaknesses depending on their intended function. Furthermore, establishing consensus guidelines for clinical and nonclinical applications of biosensor technology will likely require collaboration over multiple research groups to perform large-scale analyses of continuous TAC data over drinking and non-drinking events, comparison of output from different device types (e.g., SCRAM-CAM anklet versus newer wrist-worn devices), examination of individual TAC features such as those described by Russell et al. (2022), and integration of TAC with corresponding EMA and BAC/BrAC data. Such efforts could pay off greatly by facilitating the development of software to automatically clean TAC data, eliminate artifacts, and detect drinking events. Relatedly, the application of sophisticated analysis techniques such as machine learning (Fairbairn et al., 2020) to large and diverse datasets of TAC data and associated drinking-related consequences could provide valuable insights into how TAC features may be used as independent predictors of behavioral or health outcomes of interest. Future efforts in this area will benefit from repositories of data from across multiple research groups, such as the National Institute on Alcohol Abuse and Alcoholism's data archive (https://nda.nih.gov/niaaa).

In sum, the paper by Russell et al. (2022) presents an intriguing approach to analyzing TAC data beyond its utility as a proxy measure of BAC and intoxication. Their data indicate that examining individual TAC features may help researchers identify both behavioral and physiological risk factors for alcohol-related problems. As alcohol biosensor technology advances, we expect that these devices will become more widely deployed across the alcohol research field. Integrating TAC with real-time data on alcohol consumption and follow-up reports on consequences via EMA will further the field's understanding of the link between TAC, drinking behavior, and related outcomes. We encourage scientists in this area to collaborate to explore these associations and establish best-practice guidelines for the analysis and presentation of TAC data.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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REFERENCES

Alessi, S.M., Barnett, N.P. & Petry, N.M. (2019) Objective continuous monitoring of alcohol consumption for three months among alcohol use disorder treatment outpatients. *Alcohol*, 81, 131–138.

Barnett, N.P., Celio, M.A., Tidey, J.W., Murphy, J.G., Colby, S.M. & Swift, R.M. (2017) A preliminary randomized controlled trial of contingency management for alcohol use reduction using a transdermal alcohol sensor. *Addiction*, 112, 1025–1035.

Barnett, N.P., Meade, E.B. & Glynn, T.R. (2014) Predictors of detection of alcohol use episodes using a transdermal alcohol sensor. *Experimental and Clinical Psychopharmacology*, 22, 86–96.

Fairbairn, C.E., Kang, D. & Bosch, N. (2020) Using machine learning for real-time BAC estimation from a new-generation transdermal biosensor in the laboratory. *Drug and Alcohol Dependence*, 216, 108205.

Fell, J.C. & Scolese, J. (2021) The effectiveness of alcohol monitoring as a treatment for driving-while-intoxicated (DWI) offenders: a literature review and synthesis. *Traffic Injury Prevention*, 1–7.

Fridberg, D.J., Cao, D. & King, A.C. (2015) Integrating alcohol response feedback in a brief intervention for young adult heavy drinkers who smoke: a pilot study. *Drug and Alcohol Dependence*, 155, 293–297.

Hill-Kapturczak, N., Roache, J.D., Liang, Y., Karns, T.E., Cates, S.E. & Dougherty, D.M. (2015) Accounting for sex-related differences in the estimation of breath alcohol concentrations using transdermal alcohol monitoring. *Psychopharmacology (Berl)*, 232, 115–123.

Kappenman, E.S. & Luck, S.J. (2016) Best practices for event-related potential research in clinical populations. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, 1, 110–115.

Luczak, S.E. & Rosen, I.G. (2014) Estimating BrAC from transdermal alcohol concentration data using the BrAC Estimator software program. *Alcoholism, Clinical and Experimental Research*, 38, 2243–2252.

Richards, V.L., Liu, Y., Orr, J., Leeman, R.F., Barnett, N.P., Bryant, K. et al. (2021) Sociodemographic and clinical factors associated with transdermal alcohol concentration from the SCRAM biosensor among persons living with and without HIV. *Alcoholism, Clinical and Experimental Research*, 45, 1804–1811.

Russell, M., Turrisi, R. & Smyth, J. (2022) Transdermal sensor features correlate with ecological momentary assessment drinking reports and predict alcohol-related consequences in young adults' natural settings. *Alcoholism: Clinical and Experimental Research*, 46, 100–113.

Swift, R.M. (1993) Transdermal measurement of alcohol consumption. *Addiction*, 88, 1037–1039.

Wang, Y., Fridberg, D.J., Leeman, R.F., Cook, R.L. & Porges, E.C. (2019) Wrist-Worn alcohol biosensors: strengths, limitations, and future directions. *Alcohol*, 81, 83–92.

Wang, Y., Fridberg, D.J., Shortell, D., Leeman, R.F., Barnett, N.P., Cook, R.L. et al. (2021) Wrist-worn alcohol biosensors: applications and usability in behavioral research. *Alcohol*, 92, 25–34.