Gait & Posture 60 (2018) 116–121

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Using phone sensors and an artificial neural network to detect gait changes during drinking episodes in the natural environment

Brian Suffoletto[a,*], Pedram Gharani[b], Tammy Chung[c], Hassan Karimi[b]

[a] Department of Emergency Medicine, University of Pittsburgh School of Medicine, United States
[b] Department of Informatics & Networked Systems, School of Computing and Information, University of Pittsburgh, United States
[c] Department of Psychiatry, University of Pittsburgh School of Medicine, United States

ARTICLE INFO

Keywords:
Gait
Balance
Impairment
Alcohol
Technology

ABSTRACT

Background: Phone sensors could be useful in assessing changes in gait that occur with alcohol consumption. This study determined (1) feasibility of collecting gait-related data during drinking occasions in the natural environment, and (2) how gait-related features measured by phone sensors relate to estimated blood alcohol concentration (eBAC).

Methods: Ten young adult heavy drinkers were prompted to complete a 5-step gait task every hour from 8pm to 12am over four consecutive weekends. We collected 3-axis accelerometer, gyroscope, and magnetometer data from phone sensors, and computed 24 gait-related features using a sliding window technique. eBAC levels were calculated at each time point based on Ecological Momentary Assessment (EMA) of alcohol use. We used an artificial neural network model to analyze associations between sensor features and eBACs in training (70% of the data) and validation and test (30% of the data) datasets.

Results: We analyzed 128 data points where both eBAC and gait-related sensor data were captured, either when not drinking (n = 60), while eBAC was ascending (n = 55) or eBAC was descending (n = 13). 21 data points were captured at times when the eBAC was greater than the legal limit (0.08 mg/dl). Using a Bayesian regularized neural network, gait-related phone sensor features showed a high correlation with eBAC (Pearson's r > 0.9), and > 95% of estimated eBAC would fall between −0.012 and +0.012 of actual eBAC.

Conclusions: It is feasible to collect gait-related data from smartphone sensors during drinking occasions in the natural environment. Sensor-based features can be used to infer gait changes associated with elevated blood alcohol content.

1. Introduction

Acute alcohol intoxication is associated with numerous health risks. For example, impaired driving due to alcohol was implicated in 28% of the 38,000 deaths from motor vehicle accidents in the US in 2016 [1]. These consequences largely stem from alcohol's detrimental effects on psychomotor performance [2]. Compounding this risk are impaired decision-making [3] and lack of awareness of the degree of alcohol-related impairments during drinking episodes [4]. Strategies to measure alcohol-related psychomotor impairments and provide real-time feedback to individuals could deter involvement in activities that require psychomotor function (i.e., driving), thus reducing likelihood of injury [5].

Using alcohol consumption as a surrogate for psychomotor impairment can be prone to either underestimations (e.g. when individuals do not report alcohol consumption accurately [6]) or over-estimations (e.g. in individuals with high tolerance to the effects of alcohol [7]). Therefore, asking individuals to input drinks in real time may not be the most accurate estimate of psychomotor impairment. One measure of psychomotor performance that is particularly sensitive to alcohol is gait. Gait requires coordination of multiple sensory and motor systems. Both postural stability [8] and gait [9] are sensitive to blood alcohol concentration (BAC) levels. Although law enforcement professionals have used subjective performance on a heel-to-toe tandem gait task as a field sobriety test for years, there is no current process to objectively measure aspects of gait during drinking occasions in the natural environment.

The rapid growth of smartphone ownership [10] and standard inclusion of accelerometer and gyroscope sensors within phones suggests that these devices could be useful to objectively measure gait impairment during drinking episodes. Researchers have begun to model the associations between gait abnormalities detected using smartphone sensors and either real or simulated alcohol consumption [11,12], but no one has determined if it is feasible to collect standardized gait data

* Corresponding author at: Iroquois Building, Suite 400A; 3600 Forbes Avenue; Pittsburgh, PA 15261, United States.

https://doi.org/10.1016/j.gaitpost.2017.11.019
Received 23 June 2017; Received in revised form 10 October 2017; Accepted 20 November 2017

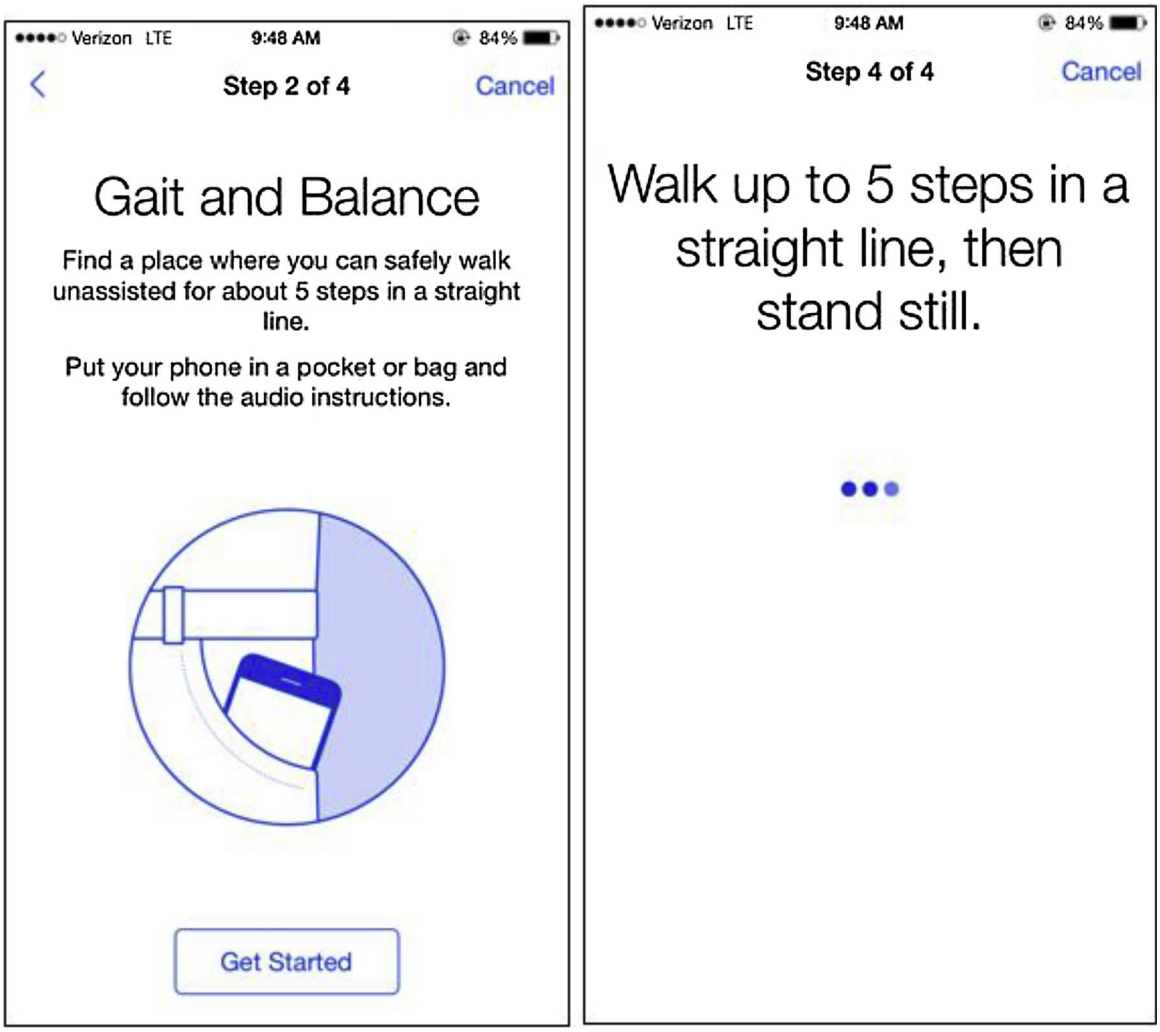

Fig. 1. DrinkTRAC app screen shots of the tandem gait task.

in the natural drinking environment from at-risk individuals, nor the association of gait features with BAC levels. Answers to these questions are critical if sensor based data will be used to provide feedback that is specific to drinking risk level.

The aim of this project was to determine (1) feasibility of collecting gait-related data during a brief gait task during drinking occasions from at-risk young adults in the natural environment, and (2) how gait-related features measured through phone sensors relate to estimated blood alcohol concentration (eBAC). To accomplish these aims, we designed an iPhone app (DrinkTRAC) to collect smartphone sensor-based data on gait (3-axis accelerometer, gyroscope, magnetometer) and ecological momentary assessment (EMA) measures of self-reported number of drinks consumed each hour, from 8pm to 12am, during weekend evenings (Fridays and Saturdays). We enrolled 10 young adults with a history of heavy drinking in a repeated-measures study to provide smartphone sensor and self-report data over a period of four consecutive weeks. We used a Bayesian regularized neural network (BRNN) to perform regression analysis to examine the association of sensor data with eBACs. Results from this work could be useful in designing effective prevention interventions to reduce risky behaviors during periods of alcohol intoxication.

2. Methods

2.1. Participants

A convenience sample of young adults (aged 21–26 years) who presented to an urban Emergency Department (ED) between February 19 and May 9, 2016 were recruited. A total of 28 medically stable ED patients who were not seeking treatment for substance use, not intoxicated, and who were going to be discharged to home, were approached by research staff. Among those eligible to be approached, 23 patients provided consent to complete an alcohol use severity screen. Those who reported recent hazardous alcohol consumption based on an Alcohol Use Disorder Identification Test for Consumption (AUDIT-C) score of ≥ 3 for women or ≥ 4 for men [13] and who drank primarily on weekends were eligible for participation. We excluded those who reported any medical condition that resulted in impaired thinking or memory or gait, those who reported past treatment for alcohol use disorder, and those without an iOS phone. A total of 10 participants met the study enrolment criteria. All participants completed informed consent protocols prior to study procedures and were provided with resources for alcohol treatment.

2.2. DrinkTRAC application

The DrinkTRAC app was developed using Apple's ResearchKit platform, as it allows for convenient and professional-appearing