Toxiter: A Rapid, Non-Invasive Technology for Objective Assessment and Quantification of THC-Induced Functional Impairment

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Revolutionizing the Assessment of Human Motion

- We have developed a ML/AI-driven digital twin and digital biomarker platform to analyze human motion and postural stability.

- Objective, quantifiable assessment of musculoskeletal and neuromuscular pathology.

- We make possible assessments that are either impractical to collect or reliant on subjective, time-consuming manual observations.

- We provide a novel, non-invasive approach to quantify xenobiotic induced functional impairment, for clinical, research and public safety applications.

"Field Sobriety Tests and THC Levels Unreliable Indicators of Marijuana Intoxication"

Biofluid levels of THC did not correlate with field sobriety test performance or marijuana intoxication, regardless of how the cannabis was ingested.

NIJ National Institute of Justice
STRENGTHEN SCIENCE. ADVANCE JUSTICE.

Field Sobriety Tests and THC Levels Unreliable Indicators of Marijuana Intoxication

Researchers investigated how marijuana affects skills required for safe driving and found that biofluid levels of THC did not correlate with field sobriety test performance or marijuana intoxication, regardless of how the cannabis was ingested.

Published in final edited form as:
J Psychopharmacol. 2021 July ; 35(7): 786–803. doi:10.1177/02698811211021583.

Assessment of cognitive and psychomotor impairment, subjective effects, and blood THC concentrations following acute administration of oral and vaporized cannabis

Tory R Spindle[1], Erin L Martin[2], Megan Grabenauer[3], Thomas Woodward[4], Michael A Milburn[5], Ryan Vandrey[1]

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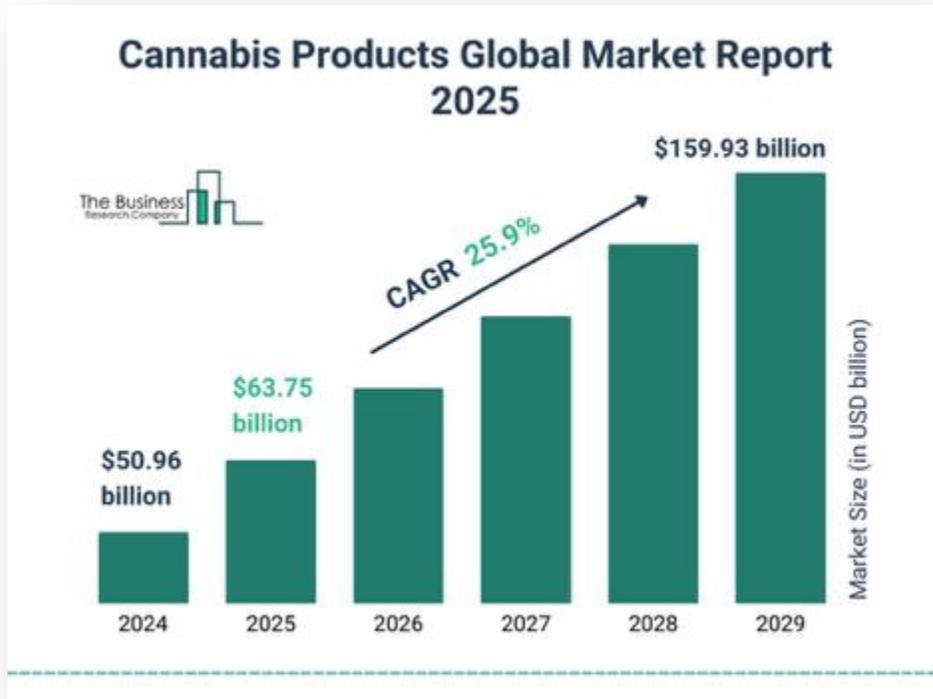
[3]RTI International, Research Triangle Park, NC, USA

[4]Maryland State Police, Pikesville, MD, USA

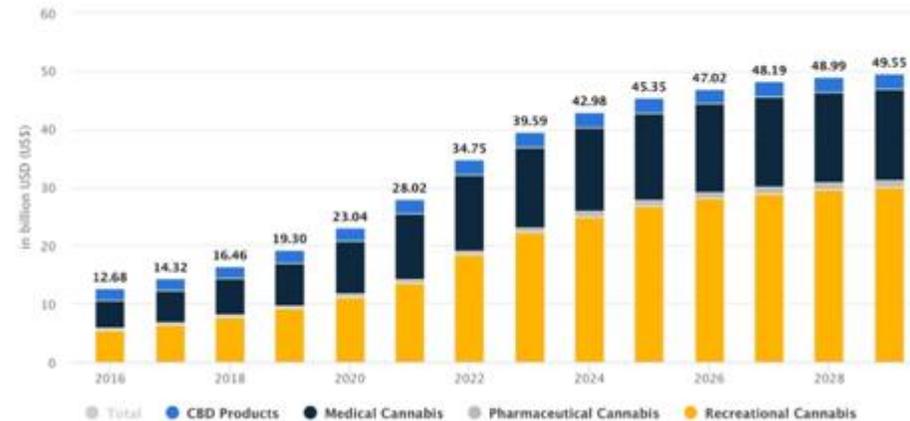[5]Impairment Science, Inc., Cambridge, MA, USA

Cannabis Expansion and the Growing Need for Testing Solutions

Cannabis Products Global Market Report 2025

The Business Research Company

CAGR 25.9%

$159.93 billion

$63.75 billion

$50.96 billion

Market Size (in USD billion)

2024 2025 2026 2027 2028 2029


The US cannabis industry is expected to reach almost $45 billion in revenue in 2025

According to projections from Statista, total revenue from cannabis is expected to reach $45.3 billion in 2025.

12.68 14.32 16.46 19.30 23.04 28.02 34.75 39.59 42.98 45.35 47.02 48.19 48.99 49.55

in billion USD (US$)

2016 2018 2020 2022 2024 2026 2028

Total ● CBD Products ● Medical Cannabis Pharmaceutical Cannabis ● Recreational Cannabis

Disequilibrium and Motor Impairment

- THC disrupts functioning of the cerebellum and basal ganglia, brain areas that regulate balance, posture, coordination, and reaction time.

- People under the influence of THC may not be able to drive safely and may have problems engaging in physical activities.

- No direct relationship between blood THC concentration and impaired driving ability.
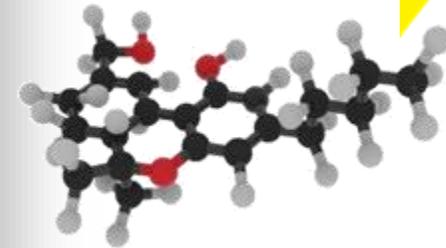
Detecting THC Mediated Motor Impairment

- Non-Invasive, Rapid and Accurate field sobriety test for THC Intoxication.

- Machine Learning/Artificial Intelligence based analysis of disequilibrium using a single motion sensor.

- Simple to operate, portable, connected sensor.

- Assessment is of actual impairment, not drug concentration in bodily fluids.
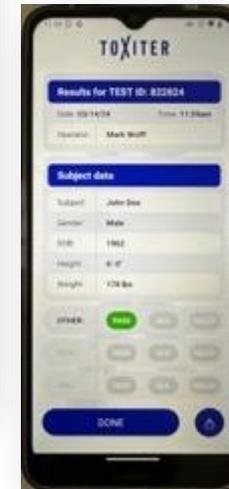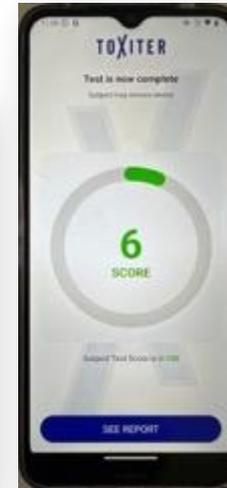
Detecting Drug Mediated Functional Impairment

Detecting Ethanol Induced Impairment
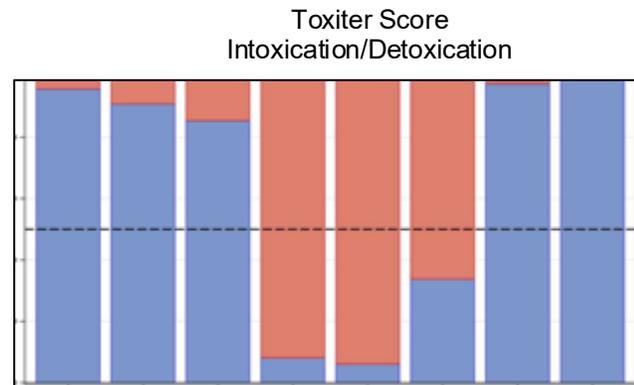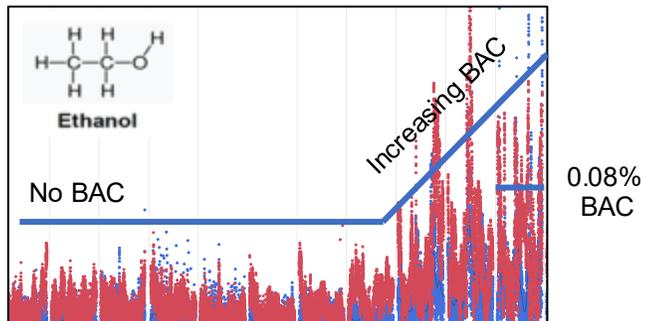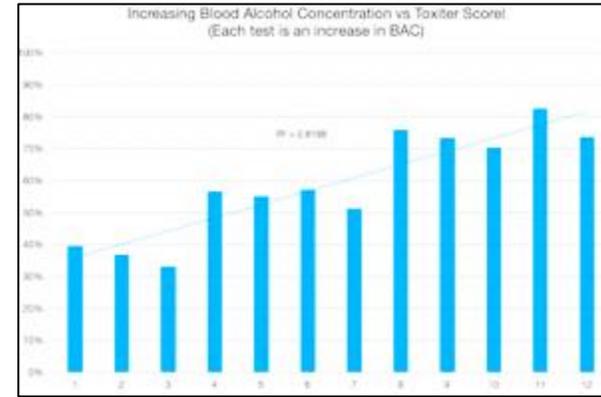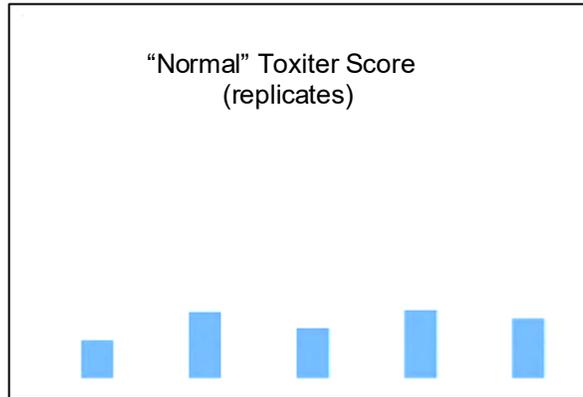
"Normal" Toxiter Score
(replicates)

Increasing Blood Alcohol Concentration vs Toxiter Score!
(Each test is an increase in BAC)

Ethanol

No BAC

Increasing BAC

0.08% BAC

Toxiter Score
Intoxication/Detoxication

"Green Lab"

Officer Jayme Derbyshire

- Montgomery County Department of Police, Gaithersburg, Maryland
- Cannabis Impairment Detection Lab
- Coordinator of the Chemical Test for Alcohol Unit, Traffic Division.
- Implemented one of the first police-hosted Cannabis Impairment Detection Labs and is presently the training coordinator.

SFST Scoring Sheet

Modified Rhomberg Balance Test Assessment
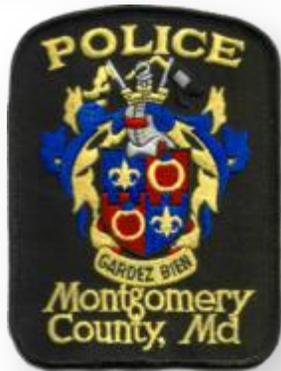
Assessment Criteria for the Modified Romberg Balance Test

Instructions to Subject:
- Stand straight with feet together.
- Tilt head slightly back (30 degrees) and **close eyes**.
- Estimate **30 seconds** silently.
- When the subject believes 30 seconds have passed, they say "stop."

Time Estimation Accuracy:
Officer uses a timer.

Normal range: 25–35 seconds.
- Significant under- or over-estimation can suggest central nervous system (CNS) impairment

Sway or Balance Issues:
- Amount of **body sway** observed while standing with eyes closed.
- **Slight sway** is normal. **Pronounced sway, hopping, or falling** suggests impairment.

Muscle Tone:
- Officer may note whether the subject shows signs of **muscle rigidity** or **flaccidity**, which are indicators of specific drug categories.

Eye or Head Movements:
- Tremors, eyelid fluttering, or inability to keep head tilted may also be noted.

Sensor Data Collection Overview

Capture real-time postural stability using inertial measurements during the Romberg test.

Sensor Modalities:
- Accelerometer (ACC):
- Measures linear acceleration
- Axes: X, Y, Z
- Gyroscope (GYRO):
- Measures angular velocity
- Axes: X, Y, Z

Sampling Rate:
- 10 to 50 Hz

Data Collected:
- Timestamp: Millisecond-resolution time series
- ACC_X, ACC_Y, ACC_Z: Acceleration in each spatial axis (m/s²)
- GYRO_X, GYRO_Y, GYRO_Z: Angular velocity around each axis (°/s)

Recording Context:
- Each subject stood in a standardized posture
- Data captured over ~30 seconds per trial
- Multiple trials across baseline (nominal) and THC-treated conditions

Postural Sway Metrics: Analytical Transformations

Extract meaningful indicators of postural control and instability from raw inertial sensor data.

Spatial-Domain Metrics:
- Mean Velocity – Average sway speed; ↑ suggests instability
- Confidence Ellipse Area – 95% area enclosing sway; reflects variability
- RMS COP – Root mean square of center-of-pressure sway; indicates sway magnitude
- Path Length – Total distance of sway path; reflects postural effort
- Sway Area per Second – Spatial control efficiency over time

Acceleration-Based Metrics:
- Mean / SD / RMS Acceleration (X, Y, Z) – Average, variability, and magnitude of linear movement
- Jerk (SD) – Smoothness of movement; ↑ = erratic/jittery motion

Gyroscope-Based Metrics:
- Mean / SD / RMS Angular Velocity (X, Y, Z) – Rotation-based metrics capturing head/body movement
- al Stability Statistical Metrics -Toxiter Inertial Sensor Analysis

Frequency-Domain Metrics:
- Total Power – Overall power in frequency domain; ↑ = more sway activity
- Centroidal Frequency – Weighted average frequency; reflects sway dynamics
- Frequency Dispersion – Spread of frequency components; indicates variability

Rules Based Logic
Thresholding

- Applied simple heuristic rules to individual sway metrics (e.g., "path length > threshold", "jerk > nominal + 2SD")
- Aligned with clinical intuition and examiner scoring logic
- Provided initial filters for suspected impairment
- Helped identify clear outliers and gross motor deficits
- Limited sensitivity to subtle or multi-factorial impairments (e.g., may miss cases with dispersed but significant changes across metrics)

Rules Based Logic

Instability Index: Composite Measure of Postural Impairment

The index captures the multifactorial nature of balance impairment under THC influence and aligns with human assessments (e.g., officer decisions).

Construction of the Instability Index
- Created by computing the normalized average of the most informative sensor-derived metrics:
- STD_GYRO – Variability of rotational motion
- JERK_SD – Smoothness of movement (rate of change in acceleration)
- PATH_LENGTH – Total displacement of postural sway
- CONFIDENCE ELLIPSE AREA – Spatial extent of sway (95% coverage)
- MEAN VELOCITY – Average sway speed over trial duration
- SPECTRAL ENTROPY – Complexity and disorder in movement frequency

Each metric is:
- Z-scored or normalized relative to subject's nominal baseline
- Then averaged to generate a composite instability score

Statistical & Signal Processing Methods

Convert raw inertial sensor data into meaningful, quantifiable features of postural control.

Transformation & Feature Engineering

Extract high-resolution features from time-series sensor data
- Mean, SD, RMS of acceleration & gyroscope (x, y, z axes)
- Path Length, Jerk, Spectral Entropy, Frequency Metrics
- Normalized against nominal baseline to compute percent change
- Enabled group-level comparisons across dose conditions (A, B, C)
- Revealed dose-response relationships in postural control metrics

Machine Learning g Models and Model Explainability
Predicting Functional Impairment and Supporting Transparent Decision-Making

Approach:
- Trained models using labeled data (e.g., "Nominal", "THC-treated", "Arrest")
- Utilized algorithms suited for non-linear, multi-dimensional relationships:
- Random Forests/Gradient Boosting — robust to noise, good for feature importance

Input Features:
- High-resolution postural sway metrics derived from accelerometer and gyroscope data
- Included both raw and normalized (% change from baseline) values
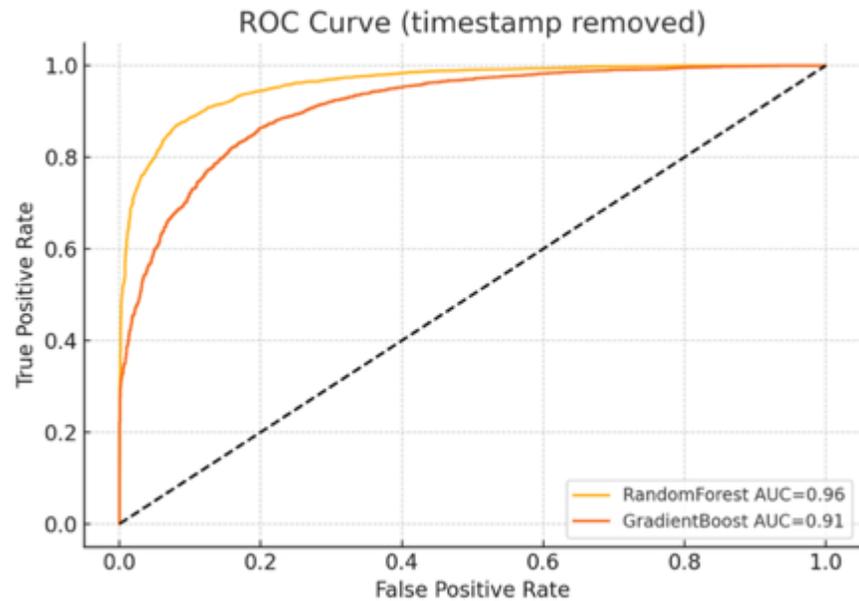
Outputs:
- Binary or probabilistic prediction of impairment or arrest
- Identification of subtle combinations of features missed by human examiners
- Performance validated using cross-validation and confusion matrices

Machine Learning Models and Model Explainability
Predicting Functional Impairment and Supporting Transparent Decision-Making

Random-Forest feature importance

(timestamp excluded — model AUC = 0.96)

Rank	Sensor-derived variable	Relative contribution (%)
1	gyro_x (e.g., SD / RMS of X-axis angular velocity)	**39.9 %**
2	**gyro_y**	15.6 %
3	**acc_x**	13.7 %
4	**gyro_z**	11.7 %
5	**acc_z**	9.6 %
6	acc_y	4.2 %
7	jerk_x	1.9 %
8	path_length	1.4 %
9	spectral_entropy	1.1 %
10	conf_ellipse_area	0.9 %
...	(remaining 20+ metrics each < 0.5 %)	

Percentages are the feature's Gini importance divided by the sum of all importances, expressed in %.
The first five motion variables explain ≈ **91 %** of the model's discriminating power.

Sensor Insights Align with Examiner Decisions

High Agreement Between Telemetry-Based Instability and Arrest Recommendations

- All subjects recommended for arrest exhibited substantial deviations in sensor-derived metrics compared to nominal conditions.
- This supports the hypothesis that sensor telemetry correlates closely with examiner judgment, especially in clear cases of impairment.

In our data:
- All telemetry deviations ≥ 50% were matched by a corresponding arrest decision
- Strongest alignment was observed for major instability patterns (e.g., high jerk, long path length, elevated spectral entropy)

Discrepancies, if present, occurred only in:
- Low-to-moderate deviation ranges
- Situations where a specific metric spiked, but the overall profile remained borderline
- These findings support the use of sensor data as a reliable, objective tool for field decision-making

T2025
TIME FOR CHANGE:
TRAFFIC SAFETY FOR A
SUSTAINABLE WORLD

24th INTERNATIONAL
CONFERENCE ON ALCOHOL,
DRUGS AND TRAFFIC SAFETY
(ICADTS)

Thank You

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