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Science, Federal Policy, Direct Advocacy, and Future Policy: Audience Perception on the Impact of Intense Caffeinated Beverages on the Human Neuromuscular System.

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Research Article

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Abstract

Background

Caffeine, the world's most widely consumed psychoactive substance, modulates neuromuscular function, enhancing reaction time, muscle contraction, and endurance at moderate doses, but provoking tremors, fatigue, and coordination deficits at high intake. Beyond physiology, public understanding of these effects is increasingly mediated by video-based content, intertwining scientific knowledge with perception, communication, and policy influence.

Objective

This study explores how audiences interpret the neuromuscular impact of intense caffeinated beverages through digital media, investigating how narrative framing shapes comprehension, emotional response, and engagement, and how these perceptions align with biomedical evidence and regulatory guidance.

Methods

Twenty-three student projects analyzing videos from TED-Ed, Institute of Human Anatomy, Doctor Mike, Dartmouth Health, and High Spirit Pharmacist were assessed using qualitative content and sentiment analysis via the Communalytic tool. Scientific accuracy, tone, and audience reactions were examined, contextualized by peer-reviewed literature and authoritative health sources (FDA, CDC, Mayo Clinic, Harvard T.H. Chan School of Public Health, 2023).

Results

Audiences universally recognized caffeine's action as an adenosine receptor antagonist and understood dose-dependent effects relative to the FDA's 400 mg/day guideline. Perceptions varied by beverage: matcha and cacao were highly favorable, coffee neutral, and soda and energy drinks elicited concern.

Engagement correlated with framing:

evidence-based videos promoted constructive discourse, whereas promotional content triggered polarized sentiment. Moderate caffeine (≤ 6 mg/kg/day) enhanced neuromuscular performance; excessive intake (> 8 mg/kg/day) induced fatigue, tremors, and receptor desensitization.

Conclusions

Audience perception is co-shaped by physiology and media framing. Translating neuromuscular science into effective public understanding requires strategic science communication, advocacy, and policy alignment. This research underscores the need for integrative approaches bridging evidence, media, and regulatory frameworks to guide safe caffeine consumption and health literacy.

Background and Theoretical Framework

The global consumption of caffeinated beverages such as coffee, matcha, chocolate-based drinks, soda, and energy drinks, has become an integral part of modern life. Caffeine, a central nervous system (CNS) stimulant, exerts profound effects on the neuromuscular system, which governs communication between the brain, spinal cord, and skeletal muscles. At the molecular level, caffeine functions primarily as an adenosine receptor antagonist, reducing neuronal inhibition and promoting increased neural excitability, prolonging reaction times, and thereby enhancing neuromuscular performance. This mechanism facilitates greater calcium ion release from the sarcoplasmic reticulum, improving actin–myosin cross-bridge cycling and contributing to increased muscle contraction strength and endurance (Davis et al., 2003; Davis and Green 2009; Spriet, 2014).

While moderate caffeine intake (up to 400 mg/day, per FDA recommendations) can enhance alertness and physical output, excessive or chronic consumption can disrupt neuromuscular equilibrium. Adverse effects include substance-induced movement disorders, eliciting twitching, tremors, tardive dyskinesia, weakness, recurring fatigue, restlessness, and impaired movement coordination, which reflect dysregulated or overstimulated neural and muscular systems. Furthermore, caffeine's impact is moderated by dosage, source, and individual sensitivity. Natural sources such as matcha and cacao are often perceived as beneficial due to their content of L-theanine and antioxidants, whereas soda and energy drinks are associated with hypokalemia, cardiovascular strain, and dependency (Mayo Clinic, 2022; FDA, 2024; Harvard School of Public Health, 2023; Harvard and Chen 2023).

Beyond its physiological implications, caffeine has also become a media-mediated scientific topic, with public perceptions increasingly shaped by how health information is framed in digital and video-based communication. Platforms such as TED-Ed, the Institute of Human Anatomy, Doctor Mike, Dartmouth Health, and High Spirit Pharmacist have emerged as popular sources of health learning for both students and the general public. These platforms combine education and entertainment, influencing how audiences interpret scientific evidence, assess risk, and form emotional or behavioral attitudes toward caffeine consumption.

Guided by this context, this study investigates audience perceptions of the impact of intense caffeinated beverages on the human neuromuscular system through a media communication lens. It explores how video-based scientific narratives influence understanding, curiosity, and concern regarding caffeine's physiological effects and how these perceptions align or diverge from biomedical evidence.

Theoretical Framework

This study draws upon two intersecting theoretical perspectives that inform both its analytical approach and interpretation:

The Health Belief and Information Processing Model (HBM/IPM)

The Health Belief Model, first developed by Rosenstock (1974) and later expanded through information processing perspectives (Janz & Becker, 1984), posits that individual health behaviors are guided by perceptions of susceptibility, severity, benefits, and barriers. In the context of caffeine consumption, these perceptions are shaped by how media messages communicate physiological risks and behavioral outcomes. The Information Processing component emphasizes how audiences encode, evaluate, and recall health messages, linking comprehension and trust to behavior change and informed decision-making.

Science Communication and Media Framing Theory

Rooted in communication studies (Entman, 1993; Nisbet, 2009), Framing Theory explains how the structure, tone, and emphasis of media messages influence public interpretation of scientific information. Educational or cautionary framing can enhance understanding and critical engagement, whereas promotional or sensational framing can distort risk perception and erode trust in scientific authority. In video-based learning environments, framing directly shapes audience sentiment, engagement, and comment tone, as identified in this study's Communalytic analysis.

Together, these frameworks support the study's dual emphasis on biological understanding and communication dynamics. By integrating neuromuscular physiology with media analysis, this research bridges the gap between scientific accuracy, audience perception, and policy translation, advancing health literacy, improving science communication, and informing future advocacy for evidence-based caffeine regulation.

Learning Objectives:

To evaluate how both scientific literature and media narratives portray caffeine's influence on the human neuromuscular system.

To analyze how learners and students of Physiology and Anatomy perceive, interpret, and emotionally respond to caffeine-related content delivered through video-based communication.

To examine the scope and limitations of current federal policies governing caffeine regulation and identify specific areas where direct advocacy can improve public health communication.

To propose evidence-informed policy recommendations that align scientific findings with federal health standards and advance consumer protection through effective science communication.

Methodology

Using Communalytic as the analytical tool, video content discussing caffeine consumption and its physiological effects was systematically collected and examined. The study employed qualitative content analysis to identify recurring themes, audience reactions, and sentiment patterns within 23 student research projects synthesizing video-based educational sources on matcha, soda, and chocolate-based caffeinated beverages.

Qualitative, video-based content and sentiment analysis was conducted across educational and medical communication platforms (TED-Ed, Institute of Human Anatomy, Dartmouth Health, Doctor Mike, High Spirit Pharmacist). Each source was analyzed for:

Scientific accuracy (alignment with physiological evidence),

Tone (educational, promotional, cautionary), and

Audience reaction (measured through comments, sentiment tone, and engagement).

Additionally, peer-reviewed articles and official health resources (FDA, CDC, Mayo Clinic, Harvard School of Public Health, 2023) provided clinical context on caffeine's neuromuscular effects and safe consumption thresholds.

Results

Table 1
Beverage-Specific caffeine Trends, Neuromuscular effects, and audience reaction

Beverage	Average Caffeine (mg) intake	Neuromuscular Effects	Audience Reaction
Coffee	80–100	Enhanced reaction time and energy; risk of tolerance	Positive (“necessary daily boost”)
Matcha (Green/Black Tea)	60–80	Balanced alertness via caffeine and L-theanine; improved coordination	Highly positive (“calm focus”)
Chocolate-Based Drinks	15–90	Mild stimulation; mood enhancement through theobromine	Neutral–positive (“healthy indulgence”)
Soda	30–70	Hypokalemia, heart arrhythmia risk, and muscle weakness	Mixed (“normalized habit”)
Energy Drinks	140–300	Tremors, anxiety, sleep disruption	Polarized/negative (“too strong,” “dangerous”)

A universal understanding (100%) of caffeine’s role as an adenosine receptor antagonist emerged across all reviewed projects, establishing this mechanism as the central explanation for caffeine’s modulation of neural excitability and motor control.

All student analyses demonstrated comprehension of dose–response relationships and acknowledged the FDA’s 400 mg/day guideline as the recognized safety threshold for adult caffeine consumption.

Perceptual Hierarchy of Caffeinated Sources

A distinct hierarchy emerged in how audiences perceived different caffeine sources:

Matcha and cacao-based beverages (67%) received positive framing, associated with “natural” origins, L-theanine synergy, and antioxidant properties.

Coffee was viewed neutrally, seen as both a productivity enhancer and a potential source of dependence or tolerance.

Soda was negatively perceived, linked to excessive sugar, hypokalemia, and cardiovascular strain.

Energy drinks evoked the most polarized reactions, cited for unregulated caffeine content, overstimulation, and appeal to youth audiences.

Neuromuscular and Physiological Themes

At the muscle physiology level (67%), findings accurately described caffeine's effect on calcium ion release from the sarcoplasmic reticulum, enhancing actin–myosin cross-bridge cycling, reaction time, and power output.

However, projects reported that higher caffeine doses reduced performance efficiency, leading to neuromuscular fatigue, substance-induced movement disorders e.g tremors, late appearing fatigue with weakness, and impaired coordination (100%).

Only 33% of analyses included discussion of tolerance mechanisms or individual variability, highlighting a knowledge gap in receptor desensitization and adaptation.

Core Audience Reactions

Using Communalytic sentiment and engagement analysis, the following trends emerged from audience comment data:

Positive reactions (40%) emphasized improved focus, motivation, and exercise performance. Viewers expressed curiosity about optimal dosage and biological mechanisms, particularly appreciating animated and visually explained videos (e.g., TED-Ed, Institute of Human Anatomy).

Neutral reactions (35%) reflected a balanced understanding, with comments highlighting moderation and appreciation for educational clarity. Many audiences acknowledged caffeine's benefits when consumed responsibly.

Cautionary or negative reactions (25%) revealed concerns about heart palpitations, sleep apnea, substance-induced muscle tension, and addiction and dependency. A subset of viewers criticized promotional or sensational content for oversimplifying physiological risks.

Students' synthesis of comment sentiment suggested that audience engagement correlates with educational tone, videos grounded in scientific explanation generated more constructive, inquisitive dialogue, whereas commercial or entertainment-oriented videos prompted emotive, polarized responses.

Platform Reliance and Communication Trends

Overall, 33% of the analyzed materials relied primarily on YouTube medical channels (e.g., Doctor Mike, High Spirit Pharmacist) as information sources, indicating strong accessibility but limited academic rigor. The remaining 67% referenced peer-reviewed materials and health agencies, reflecting growing awareness of the importance of credible science communication in shaping public understanding.

Scientific Findings

Across sources, moderate caffeine consumption (≤ 6 mg/kg body weight or ≤ 400 mg/day) improved neuromuscular function—enhancing muscle recruitment, contraction power, and fatigue delayed.

Excessive consumption (> 8 mg/kg) reversed these benefits, causing receptor desensitization, substance induced- tremors, and cardiac strain.

Matcha and coffee supported balanced cognitive and neuromuscular performance.

Energy drinks and sodas exhibited more adverse outcomes due to high caffeine and sugar content.

Hypokalemia, and arrhythmias were particularly linked to soda-based caffeine combined with diuretic effects.

Discussion

This study examined how audiences perceive the impact of intense caffeinated beverages on the human neuromuscular system through video-based educational platforms, linking scientific evidence to public understanding and policy implications. The results demonstrate that while audiences generally understand caffeine's fundamental mechanism as an adenosine receptor antagonist, perceptions vary depending on the source, framing, and beverage type.

Integration with Theoretical Frameworks

Consistent with the Health Belief Model and Information Processing perspective (Rosenstock, 1974; Rosenstock1974; Janz & Becker, 1984), audience engagement and sentiment reflected perceived susceptibility, severity, and benefits. Positive reactions toward matcha and cacao-based beverages suggest that audiences interpret "natural" sources as safer and cognitively beneficial, highlighting the importance of perceived benefits in shaping behavioral intentions. Negative responses to soda and energy drinks align with perceptions of risk, emphasizing the role of cues to action, such as warnings about hypokalemia, cardiovascular strain, and overstimulation. These findings underscore that media framing directly influences the encoding and recall of physiological information, affecting both attitudes and potential consumption behaviors.

Framing theory (Entman, 1993; Nisbet, 2009) further explains how different communication styles impact audience perception. Educationally framed videos emphasizing mechanistic explanations (e.g., calcium ion release, actin–myosin cross-bridge cycling) elicited more constructive, inquisitive engagement, whereas promotional or entertainment-oriented content prompted polarized or emotive reactions. This trend suggests that credibility and scientific rigor in media content are essential for fostering accurate understanding of caffeine's neuromuscular effects.

Comparison with Scientific Literature

The observed hierarchy of audience perception, favoring matcha and cacao over coffee, soda, and energy drinks, mirrors scientific evidence regarding both neuromuscular benefits and risks. Moderate caffeine intake (≤ 6 mg/kg or ≤ 400 mg/day) improves reaction time, muscle recruitment, and contraction strength, consistent with prior studies (Davis et al., 2003; Davis and Green 2009; Spriet, 2014).

Conversely, excessive intake (> 8 mg/kg) produces receptor desensitization, neuromuscular fatigue, tremors, and potential cardiac strain, echoing reports by Mayo Clinic (2022) and FDA guidelines (FDA, 2024). The limited discussion of tolerance mechanisms in student projects (33%) indicates a knowledge gap, suggesting a need for more explicit communication of receptor adaptation, individual variability, and cumulative consumption risks.

Implications for Policy and Advocacy

The findings highlight critical intersections among science, federal policy, and direct advocacy. While federal guidelines provide clear thresholds for safe caffeine intake, enforcement is limited, and public comprehension relies heavily on media representation. Direct advocacy by educators, clinicians, and content creators can bridge this gap, emphasizing both safe consumption practices and the physiological mechanisms underlying neuromuscular effects. Enhanced policy could include targeted public health campaigns, stricter labeling of caffeine content in energy drinks and sodas, and integration of evidence-based health literacy programs in educational curricula.

Limitations and Future Directions

This study primarily focused on student analyses and comment sentiment on English-language video platforms, which may limit generalizability. Future research should expand cross-cultural analyses, include longitudinal tracking of audience behavior following exposure to educational content, and examine other neuromodulatory substances in combination with caffeine. Additionally, integrating quantitative metrics of neuromuscular performance with audience perception data could strengthen causal inferences regarding knowledge translation and behavior.

Conclusion

Overall, this research illustrates that audience perception of caffeinated beverages is shaped by both scientific knowledge and media framing. Moderate consumption aligns with neuromuscular benefits, while excessive intake poses tangible risks. Effective science communication, aligned with federal policy and proactive advocacy, is essential to translating evidence into informed public behavior. By bridging the gap between physiology, policy, and perception, this study supports the development of future policies that promote health literacy, mitigate risk, and empower audiences to make informed choices regarding caffeine consumption.

Declarations

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Declaration:

Author Contribution

T.M. wrote the main manuscript text and prepared figures. Author reviewed the manuscript.

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