**Effect of Gamification With Social Incentives on Daily Steps After Stroke: A Randomized Clinical Trial**

The annual costs of stroke in the US have exceeded $30 billion and are largely attributed to poststroke morbidity. Regular physical activity after stroke is associated with reduced morbidity and helps prevent recurrent strokes, but some individuals remain inactive. Previous interventions were primarily delivered in clinics and lacked support to facilitate skill translation to homes. Remote, individualized interventions paired with behavioral economic principles are efficacious for increasing physical activity but are untested in patients with stroke. We assessed the effect of gamification with social incentives on daily steps among community-dwelling adults with stroke.

**Methods** | The protocol for this randomized clinical trial (NCT04607811) was approved by the University of Pennsylvania institutional review board (Supplement 1). Recruitment occurred from November 2020 to May 2021. Study details are reported elsewhere. This study followed the CONSORT reporting guideline; the CONSORT diagram and exclusion reasons are given in eFigures 1 and 2 in Supplement 2. Participants were adults who had a stroke 3 months or more before enrollment, were not receiving physical therapy, and did not have cognitive impairment. Participants provided informed consent online using a remote monitoring platform.

Participants were randomized 1:1 to a control arm or a gamification with social incentives arm, received a wearable device worn on the unaffected wrist, and selected a step goal that was a 33%, 40%, or 50% increase from their baseline. The control arm received device feedback and no further intervention. The gamification arm engaged in an 8-week game with loss-framed points and levels to help achieve their step goal and received daily (text message) and weekly (email) feedback describing their progress. Participants selected a support partner who identified 3 goals and received weekly email updates on the participant's progress.

Consistent with previous work, data were considered missing if the participant did not record a step value or if total steps were fewer than 1000 per day (10.2% of data). We used multiple imputation for missing data, and model results were pooled using Rubin standard rules.

We assessed our primary outcome (change in daily steps from baseline) using a linear mixed-effects model adjusted for participant random effects, baseline steps, and calendar month. Our secondary outcome (difference in the proportion of days participants achieved their step goal) was examined using a generalized mixed-effects model adjusted for participant random effects and calendar month. We performed 1000 bootstrap samples. Analyses were conducted in R, version 3.6.1 using 2-sided hypothesis tests, with P < .05 indicating significance.

### Table. Demographics of Trial Participants With Stroke

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Control arm (n = 17)</th>
<th>Gamification and social incentives arm (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>61 (16.9)</td>
<td>57 (13.8)</td>
</tr>
<tr>
<td>Gender, No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>11 (64.7)</td>
<td>11 (64.7)</td>
</tr>
<tr>
<td>Male</td>
<td>6 (35.3)</td>
<td>6 (35.3)</td>
</tr>
<tr>
<td>Race and ethnicity, No. (%)a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian, non-Hispanic</td>
<td>2 (11.8)</td>
<td>1 (5.9)</td>
</tr>
<tr>
<td>Black or African American, non-Hispanic</td>
<td>3 (17.6)</td>
<td>2 (11.8)</td>
</tr>
<tr>
<td>White, non-Hispanic</td>
<td>12 (70.6)</td>
<td>14 (82.4)</td>
</tr>
<tr>
<td>Married, No. (%)</td>
<td>11 (64.7)</td>
<td>12 (70.6)</td>
</tr>
<tr>
<td>Household income&gt;$50 000, No. (%)</td>
<td>15 (88.2)</td>
<td>12 (70.6)</td>
</tr>
<tr>
<td>Baseline measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke chronicity, mean (SD), mo</td>
<td>39.2 (82.1)</td>
<td>16.2 (9.2)</td>
</tr>
<tr>
<td>Ischemic stroke, No. (%)</td>
<td>12 (70.6)</td>
<td>11 (64.7)</td>
</tr>
<tr>
<td>Mini MoCA score, mean (SD)b</td>
<td>12.5 (1.2)</td>
<td>12.8 (1.2)</td>
</tr>
<tr>
<td>Body mass index, mean (SD)c</td>
<td>30.9 (7.5)</td>
<td>30.4 (6.7)</td>
</tr>
<tr>
<td>Charlson Comorbidity Index score, median (IQR)</td>
<td>2 (0-4.5)</td>
<td>1 (0-8.5)</td>
</tr>
<tr>
<td>Baseline steps, mean (SD), No.</td>
<td>4312 (1515)</td>
<td>4284 (1316)</td>
</tr>
<tr>
<td>PHQ-9 score, mean (SD)d</td>
<td>3.7 (3.2)</td>
<td>4.6 (3.9)</td>
</tr>
<tr>
<td>Stroke Self-efficacy Questionnaire score, mean (SD)e</td>
<td>123 (9.7)</td>
<td>120 (12.5)</td>
</tr>
<tr>
<td>Activities-Specific Balance Confidence Scale score, mean (SD), f</td>
<td>91.1 (7.8)</td>
<td>83.1 (14.8)</td>
</tr>
<tr>
<td>FACIT Fatigue Scale score, mean (SD)g</td>
<td>43.6 (6.2)</td>
<td>40.8 (9.7)</td>
</tr>
<tr>
<td>MOS Social Support Survey score, mean (SD)h</td>
<td>81.0 (20.9)</td>
<td>77.6 (21.9)</td>
</tr>
<tr>
<td>Life-Space Mobility score, mean (SD)</td>
<td>75.3 (21.4)</td>
<td>72.2 (25.7)</td>
</tr>
</tbody>
</table>

Abbreviations: FACIT, Functional Assessment of Chronic Illness Therapy; MoCA, Mini Montreal Cognitive Assessment; MOS, Medical Outcomes Study; PHQ-9, Patient Health Questionnaire-9.

a Race and ethnicity were self-reported and are reported because of the variability in stroke prevalence and outcomes by race and ethnicity.

b Administered via telephone; scores range from 0 to 15, with scores of 11 or higher indicating no cognitive impairment.

c Calculated as weight in kilograms divided by height in meters squared.

d Scores range from 0 to 27, with higher scores indicating more severe depression.

© 2022 American Medical Association. All rights reserved.

Downloaded From: https://jamanetwork.com/ on 09/29/2023
Results | A total of 34 participants were randomized (17 in each arm) and included in the analysis; 23 participants (67.6%) had an ischemic stroke, and the mean (SD) time since stroke was 27.7 (58.7) months (Table). Baseline steps were similar in the control (mean [SD], 4312 [1515]) and gamification (mean [SD], 4284 [1316]) arms.

Unadjusted daily steps are presented in Figure A. In adjusted analyses, the gamification arm had a significantly greater increase in mean daily steps from baseline (981 steps; 95% CI, 201-1762 steps; \( P = .01 \)) compared with the control arm. The proportion of days participants met their step goal was significantly higher in the gamification arm (adjusted difference, 0.41; 95% CI, 0.38-0.43; \( P < .001 \)); unadjusted mean proportions are presented in Figure B.

Discussion | In this trial, gamification with social incentives significantly increased daily steps among community-dwelling adults with stroke. To our knowledge, previous interventions required in-person visits, limiting access and scalability, and did not include behavioral economic principles. This trial eliminated in-person visits, incentivized individuals to increase activity at home, and did not rely on clinic to home skill translation.

Limitations include the sample size and lack of follow-up. These data may inform a future clinical trial with a larger sample of patients earlier after stroke and follow-up to evaluate long-term impact. Remote interventions that incorporate scalable technologies with behavioral economic principles may be critical for mitigating health care costs and improving long-term outcomes.

Kimberly J. Waddell, PhD, MSCI
Mitesh S. Patel, MBA, MD
Kayla Clark, BS
Tory O. Harrington, MHCI
S. Ryan Greysen, MD, MHA

Author Affiliations: Corporal Michael J. Crescenz Department of Veterans Affairs Medical Center, Philadelphia, Pennsylvania (Waddell); Ascension Health, St Louis, Missouri (Patel); Center for Health Incentives and Behavioral Economics, University of Pennsylvania, Philadelphia (Clark); Continuum Clinical, Chicago, Illinois (Harrington); Perelman School of Medicine, University of Pennsylvania, Philadelphia (Greysen).

Accepted for Publication: January 21, 2022.
Published Online: March 28, 2022. doi:10.1001/jamaneurol.2022.0231
Corresponding Author: Kimberly J. Waddell, PhD, MSCI, Corporal Michael J. Crescenz Department of Veterans Affairs Medical Center, 423 Guardian Dr, Blockley Hall 1005, Philadelphia, PA 19104 (Kimberly.Waddell@pennmedicine.upenn.edu).

Author Contributions: Drs Waddell and Greysen had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Waddell, Patel, Greysen.

Acquisition, analysis, or interpretation of data: Waddell, Clark, Harrington, Greysen.

Drafting of the manuscript: Waddell, Harrington.

Critical revision of the manuscript for important intellectual content: Waddell, Patel, Clark, Greysen.

Statistical analysis: Waddell.

Obtained funding: Waddell, Greysen.

Administrative, technical, or material support: Clark, Harrington, Greysen.

Supervision: Patel.

Conflict of Interest Disclosures: Dr Waddell reported receiving regular income from the Department of Veterans Affairs Advanced Fellowship Program in Health Services Research and Development outside the submitted work. Dr Patel reported receiving research funding from Deloitte Consulting LLP outside the submitted work, receiving personal fees as founder of Catalyst Health Resources LLC, and serving as an advisory board member of Healthmine Services Inc, LifeVest Health, and Holistic Industries. No other disclosures were reported.

Funding/Support: This study was supported by grant NIH UL1 TR00003 from the Institute for Translational Medicine and Therapeutics and the Center for Health Incentives and Behavioral Economics at the University of Pennsylvania (Dr Greysen).

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Data Sharing Statement: See Supplement 3.


Identification and Treatment of Neonatal Seizures During Therapeutic Hypothermia and Rewarming

To the Editor We read with interest the article by Chalak et al\(^1\) on the association of increased seizures during rewarming with abnormal neurodevelopmental outcomes at 2-year follow-up. The authors observed adverse neurodevelopmental outcomes among infants with seizures during rewarming after completing therapeutic hypothermia for hypoxic ischemic encephalopathy. Compared with infants without seizures during rewarming, infants with these seizures were more likely to have abnormal background amplitude integrated electroencephalography (aEEG) and an incidence of basal ganglia-thalamic injury that was 2-fold higher than that of white matter injury. This study highlights the need to optimize seizure identification, quantification, and treatment.

In the current study,\(^2\) similar to what is previously known in the literature, most seizures were subclinical; only 21% of patients had electrographic seizures on aEEG and clinical manifestations requiring phenobarbital. Although aEEG is an excellent bedside tool that helps clinicians identify electrographic seizures, it may also potentially lead to an underestimation of seizures because of an inability to detect low-amplitude/brief-duration seizures and those occurring away from the aEEG leads.\(^2,3\) Video EEG is considered the criterion standard for identifying neonatal seizures and cerebral function monitoring. Therefore, it should be considered in future studies in order to have a comprehensive assessment.

We appreciate the authors’ explanation regarding a rationale to use a time period immediately before rewarming and studying mean seizure severity scores for their analysis. There is published evidence that increasing seizure burden is associated with more severe brain injury and worse neurodevelopmental outcomes.\(^4\) Although seizure severity scores may be helpful, they fail to assess short-duration seizures or accurately inform total seizure burden, and their validity is questionable.\(^5\)

Improved electrographic seizure control during therapeutic hypothermia has the potential to improve outcomes. However, there are legitimate concerns that inappropriate use of antiepileptic drugs (AEDs) may have deleterious effects on a developing brain.\(^6\) Therefore, it is pertinent to ensure that we study not only seizure burden, but also cumulative AED exposure when assessing long-term outcomes. Studying administration of AEDs as a binary variable as used by the study authors\(^1\) may confound long-term developmental assessment.

We applaud the authors for accomplishing an important step in the understanding of seizures during rewarming and for opening the discussion regarding methods that can improve neurologic outcomes. There is clearly a need to continue to study how the process of rewarming after therapeutic hypothermia treatment completion can be further refined.

Sourabh Verma, MD
Sean M. Bailey, MD
Pradeep V. Mally, MD

Author Affiliations: Division of Neonatology, Department of Pediatrics, NYU Grossman School of Medicine, New York, New York.

Corresponding Author: Sourabh Verma, MD, Division of Neonatology, Department of Pediatrics, NYU Grossman School of Medicine, 317 E 34th St, Ste 902, New York, NY 10016 (sourabh.verma@nyulangone.org).

Published Online: April 4, 2022. doi:10.1001/jamaneurol.2022.0436

Conflict of Interest Disclosures: None reported.


In Reply Verma and colleagues discuss future research directions after our Original Investigation\(^1\) published in the December 2021 issue of *JAMA Neurology*. The Systematic Monitoring of Electroencephalography (EEG) in Asphyxiated Newborns During Rewarming After Hypothermia Therapy (SMART) study is the largest cohort that used continuous 2-channel EEG to assess the frequency of electrographic seizures before and during rewarming, which resulted in twice higher odds of electrographic seizures observed during rewarming. The higher odds of seizures observed were associated with a significantly higher risk of death or moderate-severe disability at 18 to 22 months of age.\(^1\)

The SMART study highlighted important knowledge gaps that should be considered in future investigations: (1) it is still unknown whether the treatment of subclinical EEG seizures observed during rewarming is beneficial, and (2) it is not known whether slowing the rate of rewarming from 0.5 °C to 1 °C per hour would result in reduced seizures and improved neurodevelopmental outcomes. There is also clearly a need to validate the seizure burden documented by amplitude EEG and to test the efficacy of antiepileptic drug (AED) treatment of the subclinical seizures identified during rewarming.