What’s the Healthiest Day?
Circaseptan (Weekly) Rhythms in Healthy Considerations

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Background: Biological clocks govern numerous aspects of human health, including weekly clocks—called circaseptan rhythms—that typically include early-week spikes for many illnesses.

Purpose: To determine whether contemplations for healthy behaviors also follow circaseptan rhythms.

Methods: We assessed healthy contemplations by monitoring Google search queries (2005–2012) in the U.S. that included the word healthy and were Google classified as health-related (e.g., healthy diet). A wavelet analysis was used in 2013 to isolate the circaseptan rhythm, with the resulting series compared by estimating ratios of relative query volume (healthy versus all queries) each day (e.g., (Monday–Wednesday)/Wednesday).

Results: Healthy searches peaked on Monday and Tuesday, thereafter declining until rebounding modestly on Sunday. Monday and Tuesday were statistically indistinguishable ($t=1.22$, $p=0.22$), but their combined mean had 30% (99% CI=29, 32) more healthy queries than the combined mean for Wednesday–Sunday. Monday and Tuesday query volume was 3% (99% CI=2, 5) greater than Wednesday, 15% (99% CI=13, 17) greater than Thursday, 49% (99% CI=46, 52) greater than Friday, 80% (99% CI=76, 84) greater than Saturday, and 29% (99% CI=27, 31) greater than Sunday. We explored media-based (priming) motivations for these patterns and they were consistently rejected.

Conclusions: Just as many illnesses have a weekly clock, so do healthy considerations. Discovery of these rhythms opens the door for a new agenda in preventive medicine, including implications for hypothesis development, research strategies to further explore these rhythms, and interventions to exploit daily cycles in healthy considerations.


Introduction

Clock-like rhythms are ubiquitous across health, seasonal variations, such as with mental illness, have been most notable. However, weekly circaseptan rhythms characterized by Monday spikes in high blood pressure, infectious disease, myocardial infarction, sinus tachycardia, and stroke also exist.

Given the week is socially constructed, the likely mechanisms driving circaseptan rhythms in illness are psychosocial and therefore relevant to health behaviors. Moreover, understanding circaseptan rhythms of health behaviors can yield critical public health gains. For instance, government-funded health promotion programs spend $76.2 billion annually, and their cost-effectiveness can be improved by targeting the population on weekday(s) when more individuals are contemplating their health habits.

Because healthy contemplations are at best recorded semi-annually, investigators have focused on annual (e.g., New Year’s day) or seasonal (e.g., winter weight gain) rather than weekly rhythms. Nonetheless, a web data revolution is changing preventive medicine by generating real-time health trends, such as those from aggregating Internet search queries. In this exploratory report, we describe daily patterns in online search queries to...
uncover circaseptan rhythms, where examining individual’s searches reveals both the searcher’s contemplations and when they are taking action toward behavior change.

Methods

Daily trends for all queries that included the word healthy in combination with other terms (e.g., healthy recipes) were downloaded from Google’s public database for 2005–2012, or 2,906 days (google.com/trends). Non–health-related searches (e.g., healthy salary) were omitted by only analyzing search trends that Google classified as health-related.16

Changes in raw search volume can be deceptive because all searches might decline during the weekend. Therefore, Google archives return relative search volume (RSV) trends, reflecting the proportion of healthy queries relative to all queries, then normalized on a 0–100 scale representing the highest observed daily search proportion (e.g., RSV=50 is 50% of the highest search proportion).

First, we used the continuous wavelet transform to identify searches’ weekly periodic component. Specifically, this approach decomposes the time series into time-frequency space (e.g., RSV per day, week, or year), thus determining the dominant decomposition time variability in the data. This approach was preferred to parametric assumptions and does not make parametric assumptions.17 Moreover, the wavelet allows examination of both the intensity and timing of periodic circaseptanality over the entire study period, which is not dually possible with a Fourier decomposition. For a comprehensive analytic treatment of the wavelet transform, see Torrence et al.18; for practical examples, see Grenfell19 and Johansson.20

Second, we reconstructed the time series with periodic components <14 days (as identified by the wavelet) after adding back the mean of the time series, as the wavelet is mean-centered. Third, we modeled the difference between Monday and other days as a difference in means, fitting a linear regression with the days of the week as a factor variable (i.e., ̂β_{Tuesday} + ̂β_{Wednesday} + ... + ̂β_{Sunday}).

Fourth, the mean search volume difference between days was described as a percentage increase by division of the regression variables (e.g., percentage difference = \( \frac{\hat{\beta}_{Tuesday}}{\hat{\beta}_{Monday}} \times 100 \)). For the latter, CIs were estimated by simulating 5,000 bootstrap replicates from the multivariate normal sampling distribution, with the mean equal to the maximum-likelihood point estimates and variance equal to the variance–covariance matrix; that is, \( \hat{\beta}_{mt} \sim \text{MVN}(\hat{\beta}_{mle}, V(\hat{\beta}_{mle})) \) where \( \hat{\beta}_{mle} \) is the vector of the regression coefficients and \( V(\hat{\beta}_{mle}) \) the variance–covariance matrix from the regression. This method allows estimation of the uncertainty in non-standard, interpretable measures (see King et al.21 for a detailed explanation and statistical justification). Ninety-nine percent CIs are presented based on a Bonferroni correction for six comparisons (7 days, one common reference).22

We crawled the U.S. Google News (news.google.com) domain for the same periods, capturing English-language coverage of “healthy” topics in newspapers/magazines and broadcast/cable networks, including online and print content. The number of articles containing healthy was divided by the number of articles containing the each day, reported per 100,000. We then tested the hypothesis that media were responsible for search patterns23 by replicating the wavelet analysis for media, and estimating Pearson correlation and a repeated measures ANOVA with within-week clustering for media compared to search trends.24 All statistical analyses were conducted in R, version 2.15.3.

Results

Healthy queries in the U.S. peaked early in the week, declining through Saturday until modestly rebounding on Sunday (Figure 1). Moreover, search volumes were more consistent by day across weeks than within weeks across days (intraclass correlation, 0.006 vs 0.740), meaning that Mondays are more like other Mondays than the neighboring Sunday or Tuesday.

Relative query volume was significantly different for each comparison except Monday versus Tuesday (t=1.22, p=0.22); thus, Monday and Tuesday were pooled for further analysis. Monday and Tuesday queries were 30% (99% CI=29, 32) greater than the combined Wednesday—Sunday mean. Moreover, healthy queries on Monday and Tuesday were 3% (99% CI=2, 5) greater than Wednesday; 15% (99% CI=13, 17) greater than Thursday; 49% (99% CI=46, 52) greater than Friday; 80% (99% CI=76, 84) greater than Saturday; and 29% (99% CI=27, 31) greater than Sunday.

Media rhythms were substantially different from search rhythms. For example, Monday was not focal for healthy media coverage: Wednesday had about 9% (99% CI=0.4, 18) greater media coverage than Monday. In addition, media trends were only loosely associated with search queries (r=0.34). Lastly, repeated measures ANOVA revealed no effect of news on search after accounting for within-week clustering (F=0.926, p=0.34). Therefore, the likely explanation for circaseptan rhythms in healthy thinking was not media priming.

Discussion

Just as many illnesses have a weekly clock, so may healthy contemplations. Investigators now have evidence to

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embark on a research agenda to further appreciate and exploit rhythms in health behaviors, including developing new hypotheses, databases, and interventions.

Hypothetically, the observed patterns suggest that health behavior contemplations are not governed by individual psychology, but rather collective behavior patterns. Therefore, the likely mechanistic factors supplanting individual psychology are the socially constructed meanings attributed to the days of the week. First, the beginning of the week may be akin to a mini New Year’s day. Second, reengagement with workweek planning may engender health-related planning. Third, healthy rhythms may be a collateral consequence of early-week spikes in poor health. Lastly, poor health choices during the weekend may promote a desire to cleanse come Monday.

Evidence cannot be presented herein to test mechanistic claims, but new databases can shed light on the ubiquity of circaseptan rhythms. Interventionists, for instance, could assess how program enrollment varies daily as a secondary aim, where enrollment may indicate healthy contemplations. Population surveys could include questions about the weekday respondents’ desire to initiate a behavior change and why. Use of service data, such as smoking quitlines, may also yield insights.25

Nevertheless, the discovery of circaseptan rhythms has strong potential for improving public health, both near- and long-term. Health promotion campaigns could immediately be made more cost effective by targeting the population early in the week rather than uniformly across the week. For instance, mass media campaigns could purchase more advertisements.

A major limitation is that we cannot precisely link our findings to raw search volumes. However, Eysenbach and Köhler estimated that 5% of all global searches are health-related, and in 2012, people searched Google 1.2 trillion times.27 Thus, a single percentage point difference may represent millions of health queries each day, meaning that a small percentage difference between Wednesday and Monday/Tuesday can have substantial practical implications.

These findings are the initial steps toward understanding recurring weekly rhythms in health contemplations. That weekly clocks also impact precise behaviors seems likely, and we hope our work encourages others to measure and leverage these rhythms in preventive medicine.

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