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No Evidence of Purported Lunar Effect on Hospital Admission Rates or Birth Rates

Jean-Luc Margot

Background: Studies indicate that a fraction of nursing professionals believe in a "lunar effect"—a purported correlation between the phases of the Earth's moon and human affairs, such as birth rates, blood loss, or fertility.

Purpose: This article addresses some of the methodological errors and cognitive biases that can explain the human tendency of perceiving a lunar effect where there is none.

Approach: This article reviews basic standards of evidence and, using an example from the published literature, illustrates how disregarding these standards can lead to erroneous conclusions.

Findings: Román, Soriano, Fuentes, Gálvez, and Fernández (2004) suggested that the number of hospital admissions related to gastrointestinal bleeding was somehow influenced by the phases of the Earth's moon. Specifically, the authors claimed that the rate of hospital admissions to their bleeding unit is higher during the full moon than at other times. Their report contains a number of methodological and statistical flaws that invalidate their conclusions. Reanalysis of their data with proper procedures shows no evidence that the full moon influences the rate of hospital admissions, a result that is consistent with numerous peer-reviewed studies and meta-analyses. A review of the literature shows that birth rates are also uncorrelated to lunar phases.

Conclusions: Data collection and analysis shortcomings, as well as powerful cognitive biases, can lead to erroneous conclusions about the purported lunar effect on human affairs. Adherence to basic standards of evidence can help assess the validity of questionable beliefs.

Key Words: bias • hemorrhage • lunar cycle • Moon • parturition • patient admission • Poisson distribution

Nursing Research, Month 2015, Vol 00, No 0, 00–00

Numerous studies have shown the absence of a lunar influence on human affairs, including automobile accidents, hospital admissions, surgery outcomes, cancer survival rates, menstruation, births, birth complications, depression, absenteeism, violent behavior, suicides, and homicides (see Foster & Roenneberg, 2008, for a recent review). Meta-analyses of dozens of studies spanning decades show that there is no foundation for the belief in a lunar effect (Byrnes & Kelly, 1992; Martens, Kelly, & Saklofske, 1988; Martin, Kelly, & Saklofske, 1992; Rotton & Kelly, 1985). Yet, some professionals who work in emergency rooms or maternity wards continue to believe that the number of hospital admissions or human births is larger during the full moon than at other times. In some cases, the tiniest deviations from randomness are used in an attempt to justify these beliefs.

To properly establish a correlation between the phases of the Moon and human affairs, one must adhere to a few basic standards of evidence. First, data collection procedures must be sound. For instance, the assignment of time tags to specific events must be precise; otherwise, an unnecessary source of error is introduced in the data. Because the lunar cycle varies in duration, a reasonable metric might be the time interval in minutes between the event under consideration and the previous or next full moon—with a transition from positive to negative values at new moon. Examples of problems related to improper time tags are reviewed in the sections on calendar, binning, and timescale issues. Second, periodicities or trends present in the data, but unrelated to the Moon, must be properly considered and controlled for; otherwise, a genuine variability may masquerade as a lunar cycle variability. Examples of mistaken attributions are discussed in the section on confounding issues. Third, rigorous statistical tests must be employed to ensure that the variability cannot be explained by chance alone,

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DOI: 10.1097/NNR.0000000000000086

and these calculations must be performed with a suitably high level of confidence; otherwise, one might "detect" an effect that is not present. The impact of flawed procedures and low confidence levels are discussed in the section on improper statistical treatment. Fourth, if a departure from expectations based on chance is detected, care must be taken to verify that this departure is truly associated with the Moon. If statistically significant deviations were to occur at random times during the lunar cycle, for instance, the Moon would have to be exonerated. The consequences of omitting this important verification step are reviewed in the section on incomplete statistical treatment. Finally, the claim of a lunar effect would have to satisfy the additional requirements of reproducibility and predictability. Similar studies by independent teams at different hospitals would have to produce similar results, and predictions based on the claimed effect would have to be tested and validated by additional data.

Studies that have claimed the existence of a lunar effect universally fail to meet the reproducibility and predictability requirements.

They also often fail to meet some of the other basic standards of evidence discussed above (Kelly, Rotton, & Culver, 1996; Rotton & Kelly, 1985). An instructive example of these shortcomings is provided by the study of Román, Soriano, Fuentes, Gálvez, and Fernández (2004). This article examines their study in some detail and also describes some of the cognitive biases that lead to questionable beliefs.

FLAWED DATA COLLECTION PROCEDURES

Data

The number of hospital admissions throughout the lunar cycle, as described by Román et al. (2004), is shown in Table 1. The data set covers a 738-day period between January 1, 1996, and January 7, 1998. The authors reported a total of 447 hospital admissions—26 of which are listed as coinciding with one of 25 "full moon days." They described the mean number of admissions per day as 1.04 (SD = 0.93) and 0.59 (SD = 0.78) for "full moon" and "non-full moon" days, respectively.

Definitions of Full Moon and Lunar Cycle

A full moon occurs when the excess of the Moon's apparent geocentric ecliptic longitude over the Sun's apparent geocentric ecliptic longitude is 180° (Urban & Seidelmann, 2012). Because the orbital velocities of the Earth and the Moon are not constant, the time interval between successive instances of the full moon is not constant. Over the duration of the Román et al. (2004) study, this interval reached a minimum of 29.28 days and a maximum of 29.80 days. Currently, the average length of the cycle of lunar phases is roughly 29.53 days.

TABLE 1. Number of Hospital Admissions

Day[a]	Admissions[b]
1	16
2	21
3	13
4	13
5	7
6	12
7	13
8	16
9	24
10	8
11	14
12	23
13	23
14	15
15	14
16	12
17	8
18	16
19	16
20	9
21	16
22	17
23	18
24	20
25	10
26	16
27	23
28	8
29	26

Note. From Román et al. (2004). [a]"Days of the lunar cycle." [b]Number of admissions reported for those days. No data were reported for Day 30.

Calendar Issues

The methodology described in Román et al. (2004) is as follows: "We determined the total number of admissions on each calendar day during the period studied and then distributed this number according to the corresponding day of the lunar month. … A full moon day was considered to be the day when the moon appears completely illuminated (100% of the moon disc)." Because there is no additional specification of the calendar that was used, one must assume that the authors used the civil calendar in force at their hospital in Barcelona, Spain. Spain has had and continues to have a complicated history of political decrees enforcing time zone changes between Coordinated Universal Time (UTC), UTC+1, and UTC+2. These decrees appear to accommodate daylight savings time as well as other time-variable preferences. Because the timing of the full moon samples the entire 24-hour calendar day, the same hospital admissions could be assigned to what the authors describe as a "full moon day" or a "non-full moon day," depending on the legislation in place at the time. Therefore, the methodology of Román et al. (2004) introduces an unnecessary source of error that can contribute to bias, variance, or both. As constructed, their data set is ill-suited to study the possibility of lunar effects and is better suited to study the possibility of cyclic effects modulated by the vagaries of legislated time zone changes—which are obviously not natural phenomena.

Binning Issues

A more serious problem with the methodology of Román et al. (2004) has to do with the assignment of hospital admissions to 1 of 29 days, with Day 29 considered the "full moon day. Román et al. (2004) used the following prescription to bin their data: "A full moon day was considered to be the day when the moon appears completely illuminated (100% of the moon disc). We considered this day to be the 29th day of the lunar calendar." Because the length of the lunar cycle is not equal to 29 days, the assignment of hospital admissions to 1 of 29 days is problematic. Specifically, the authors reported studying 25 "complete cycles" of 29 days each (a total of 25 × 29 days = 725 days), which does not match the 738 days spanned by the 25 lunar cycles that occurred during their study period. On 13 different occasions, the authors associated the full moon with the 29th day of their "lunar calendar"—even though the full moon actually coincided with the 30th day of that calendar. To illustrate, 30 days separate the full moon on January 5, 1996, from that on February 4, 1996, yet, both were labeled "Day 29" in the Román et al. (2004) study. If hospital admissions on Days 29 and 30 were combined in a single bin, it would obviously lead to an artificial increase in the number of admissions reported for Days 29 ("full moon days"). If hospital admissions on Days 29 were not counted with those on Days 30, how were those admissions treated? The Román et al. (2004) paper remains silent on this issue, leaving the methodology poorly defined. In the best-case scenario, the Román et al. (2004) procedure biases the data. In the worst-case scenario, it leads to a completely artificial (roughly 50%) increase in the number of hospital admissions reported for "full moon days."

Timescale Issues

Román et al. (2004) did not state over what timescale the purported lunar effect is supposed to take place. If the timescale were less than 24 hours, then the analysis would be faulty because it makes no distinction between a full moon that occurs at 00:00:01 or a full moon that occurs at 23:59:59. In the first case, hospital admissions in the ~24 hours *following* the full moon would count toward "Day 29" admissions, whereas in the second case, admissions in the ~24 hours *preceding* the full moon would count toward "Day 29" admissions. This unnecessary source of error in calculating the time from full moon can contribute to bias, variance, or both. If the timescale were more than 24 hours, the analysis would also be faulty because it fails to consider days adjacent to Day 29. For instance, a total of 50 hospital admissions were reported on the 3 days surrounding the full moon (29 ± 1). This amounts to an average admission rate of 0.65 admissions per day over the 738-day study period—which is statistically indistinguishable from the overall average admission rate of 0.61 admissions per day (447 admissions over 738 days).

Confounding Issues

It has been well established that day-of-week variability can explain most or all of the variance in studies claiming a lunar effect. For instance, Templer, Veleber, and Brooner (1982) asserted that the number of traffic accidents was correlated to the phases of the Moon. However, Kelly and Rotton (1983) pointed out that the pattern was more likely due to an increase in vehicular accidents during weekends. Indeed, when Templer, Brooner, and Corgiat (1983) reanalyzed their data with controls for holidays, weekends, and months of the year, the hypothesis of a lunar effect was no longer tenable. What the authors had initially observed and incorrectly ascribed to a lunar influence was merely day-of-week variability. In the case of hospital admissions, it is not difficult to imagine that variations by day of week would occur. In their analysis, Román et al. (2004) did not account for variables, such as day of week, that likely explain most of the variance in their data, casting further doubt on the validity of their conclusions.

FLAWED STATISTICAL PROCEDURES

Improper Statistical Treatment

Román et al. (2004) indicated that they performed Mann–Whitney tests of their hypotheses. The hypotheses are not clearly stated, but it appears that the authors tried to establish that the rate of hospital admissions on "full moon days" was statistically different from that on "non-full moon days." In certain situations, the Mann–Whitney test can be used to compare the equality of the means or medians of two independent groups—as long as the distributions are similar in dispersion and shape (Hollander & Wolfe, 1999). This test requires that the dependent variable be either continuous or ordinal, which is not the case for the number of hospital admissions per day because counts are discrete variables. It is possible that the data were rank-ordered, but the paper does not describe rank ordering, leaving the methodology poorly defined. In addition, Román et al. (2004) did not provide values of the Mann–Whitney U statistic, making validation of their results impossible. Furthermore, when the probability distributions of the two groups are not identical, the Mann–Whitney test cannot be used to compare the means or medians of the two groups. A difference in dispersion or shape invalidates the test (Hollander & Wolfe, 1999). As shown below in the section on variability in hospital admission rates, the distributions of hospital admissions on "full moon" and "non-full moon" days in the Román et al. (2004) data set are not the same—perhaps as a result of the procedural flaws described above—such that any conclusion about the mean or median number of hospital admissions resulting from a Mann–Whitney test must be discarded.

Additional difficulties arise when attempting to make statistical inferences and choosing relatively low confidence levels. At a 95% confidence level, five studies out of a hundred will detect an effect that is not present (type I error). When making extraordinary claims, much higher confidence levels are warranted. In addition, studies affected by Type I errors tend to be overrepresented in the literature, because the studies that fail to show a connection are more likely to remain unpublished—a publication bias known colloquially as the file drawer effect (Easterbrook, Gopalan, Berlin, & Matthews, 1991).

Incomplete Statistical Treatment

Román et al. (2004) asserted that "the number of [hospital] admissions … nearly doubled on full moon days as compared to non-full moon days." Because of improper statistical treatment, they did not correctly examine the statistical significance of this claim. Even if one were to disregard problems with the data collection and statistical treatment, the fact that the number of hospital admissions on Days 29 (M = 1.04, SD = 0.93 admissions per day) is larger than the number of admissions on other days (M = 0.59, SD = 0.78 admissions per day) does not demonstrate a causal relationship with the Moon. For instance, four separate days throughout the "lunar cycle" exhibit hospital admission rates nearly equal to the rate reported for "full moon days." Days 9 registered 24 admissions over 25 days (0.96 admissions per day), and Days 12, 13, and 27 each registered 23 admissions over 25 days (0.92 admissions per day). The differences between the number of admissions per day on Days 9, 12, 13, 27, and 29 of the cycle are *not* statistically significant. Therefore, there is no evidence that "full moon days" are associated with an unusual rate of hospital admissions.

FLAWED INTERPRETATION

The strength of lunar tides on blood was invoked as a possible explanation for the purported lunar effect (Román et al., 2004). This underscores misconceptions about tides. First, tides act on ordinary matter, whether liquid or solid. Second, the strength of tides is proportional to the mass of the tide-raising body and inversely proportional to the cube of the distance from the tide-raising body. Therefore, ordinary objects (cars, houses, hospitals, etc.) in the vicinity of a potential patient exert tides that are orders of magnitude stronger than those exerted by the Moon. In addition, the strongest lunar tides occur at both the new moon and the full moon (when the Sun, Earth, and Moon are roughly aligned), but an increase in hospital admissions at new moon was not observed—further invalidating the interpretation.

VARIABILITY IN HOSPITAL ADMISSION RATES

The data set of Román et al. (2004) suffers from a number of problems that make it unsuitable for a rigorous examination of the impact of lunar phases on hospital admission rates. The statistical treatment is inadequate and does not support the claim of a lunar influence. Nevertheless, it may be possible to use the data to investigate the variability in hospital admission rates.

The number of hospital admissions in any given time interval can be modeled by a Poisson distribution with rate λ (admissions per day). For any two Poisson processes 1 and 2 with rates λ_1 and λ_2, it is possible to test the hypothesis that one of the rates is larger than the other. The Poisson distributions representing hospital admissions over time intervals t_1 and t_2 expressed in days are given by $X_1 \propto \text{Poisson}(t_1\lambda_1)$ and $X_2 \propto \text{Poisson}(t_2\lambda_2)$. Let us represent the observed values (number of admissions) by k_1 and k_2, respectively, with $k = k_1 + k_2$.

The null and alternate hypotheses are

$$H_0\colon \frac{\lambda_1}{\lambda_2} \le 1 \quad \text{versus} \quad H_{\text{a}}\colon \frac{\lambda_1}{\lambda_2} > 1. \tag{1}$$

Przyborowski and Wilenski (1940) gave us a formalism for testing the null hypothesis. It relies on the conditional distribution X_1 given $X_1 + X_2 = k$. This distribution is binomial with k trials and a probability of success $p = t_1/(t_1 + t_2)$ for equal rates. One can reject the null hypothesis H_0 whenever

$$P(X_1 \ge k_1 | k; p) = \sum_{i=k_1}^{k} \binom{k}{i} p^i (1-p)^{k-i} \le \alpha, \tag{2}$$

where α is a given significance level. Using the 0.05 significance level chosen by Román et al. (2004) and recalling that $t_1 + t_2 = 738$ days, one can show that the hypothesis must be rejected for any day of their calendar that accumulated 23 or more hospital admissions, and this conclusion is unchanged if one assumes $t_1 + t_2 = 725$ days instead. There are five such instances. With λ_i and $\lambda_{\bar{i}}$ representing the admission rate on days i and on all other days, respectively, one finds

$$\frac{\lambda_9}{\lambda_{\bar{9}}} > 1, \frac{\lambda_{12}}{\lambda_{\bar{12}}} > 1, \frac{\lambda_{13}}{\lambda_{\bar{13}}} > 1, \frac{\lambda_{27}}{\lambda_{\bar{27}}} > 1, \frac{\lambda_{29}}{\lambda_{\bar{29}}} > 1. \tag{3}$$

Because the apparent increase in rates is observed on 5 out of 29 days—four of which are not "full moon days"—it is unjustifiable to ascribe the increase to the full moon. The logical conclusion that can be drawn from these data is that hospital admission rates on some days are higher than those on other days.

One can ask whether the variations recorded by Román et al. (2004) could have been observed under the hypothesis of a constant rate of hospital admissions. Specifically, if the process of admissions on days i is represented by $X_i \propto$

Poisson($t_i\lambda_i$), the relevant hypothesis to test is H_0: $\lambda_1 = \lambda_2 = \ldots = \lambda_{29}$. The test statistic is

$$\chi^2 = \sum_{i=1}^{29} \frac{[k_i - (k/t)]^2}{(k/t)}, \tag{4}$$

where the observed values are represented by k_i, $\sum k_i = k$, and $\sum t_i = t$. One can reject the null hypothesis H_0 whenever $P_\chi(\chi^2; \nu) \leq \alpha$, where $P_\chi(\chi^2; \nu)$ is the integral probability of exceeding χ^2 and $\nu = 28$ is the number of degrees of freedom. With $\alpha = .05$ and the data of Román et al. (2004), the null hypothesis is rejected—which could be due to the biases introduced by their binning procedure, by confounding effects such as day of week, by clerical or other errors, or by a combination of these factors.

To conclude, although the data of Román et al. (2004) exhibit variations that appear to deviate from a Poisson process with a constant rate, there is no support for the idea that the full moon is associated with the variations. This conclusion is consistent with the fact that there is no known plausible lunar-related mechanism that could explain such variations.

ANALOGY WITH BIRTH RATES

Anecdotal evidence suggests that many nurses and midwives believe that deliveries are more abundant during the full moon (e.g., Schaffir, 2006). This belief is inconsistent with the data. The landmark study was conducted at the University of California, Los Angeles. Records of 11,961 live births and 8,142 natural births (not induced by drugs or Cesarean section), over a 4-year period (1974–1978) at the University of California, Los Angeles hospital, did not correlate in any way with the cycle of lunar phases (Abell & Greenspan, 1979). The study benefited from an interdisciplinary collaboration between Abell, an astronomer, and Greenspan, a physician. This interdisciplinary model is likely to reduce the number of problems that plague studies purporting to show a lunar effect. A decade later, an extensive review of 21 studies from seven different countries showed that most studies reported no relationship between birth rate and lunar phase, and that the positive studies were inconsistent with each other (Martens et al., 1988). A review of six additional studies from five different countries showed no evidence of a relationship between birth rate and lunar phase (Kelly & Martens, 1994). Additional investigations have been published since then. An analysis of 3,706 spontaneous births (excluding births resulting from induced labor) in New York in 1994 showed no correlation with lunar phase (Joshi, Bharadwaj, Gallousis, & Matthews, 1998). The distribution of 167,956 spontaneous vaginal deliveries—at 37–40 weeks gestation, in Phoenix—between 1995 and 2000 showed no relationship with lunar phase (Morton-Pradhan, Bay, & Coonrod, 2005). Analysis of 564,039 births in a 4-year period (1997–2001) in North Carolina showed no predictable influence of the lunar cycle on deliveries or complications (Arliss, Kaplan, & Galvin, 2005). A review of 6,725 deliveries in a 6-year period (2000–2006) in Hannover, Germany, revealed no significant correlation of birth rate to lunar phase (Staboulidou, Soergel, Vaske, & Hillemanns, 2008). Because the absence of a correlation has been reported so widely, one may wonder why the belief in a lunar effect has persisted in the medical and nursing communities.

COGNITIVE BIASES

Gilovich (1993) provided a lucid and compelling explanation of several cognitive biases that affect the emergence of questionable beliefs. First, we are not very good at recognizing random data and tend to see patterns, clusters, and order even where these don't exist. Second, we are prone to ignore data that contradict our beliefs and to give undue weight to confirmatory information (i.e., data that support preestablished beliefs). Third, we tend to overestimate the fraction of people who share our beliefs, which reinforces preexisting beliefs. Gilovich (1993) emphasized that many of our questionable beliefs have purely cognitive origins and derive primarily from the "misapplication or overutilization of generally valid and effective strategies for knowing." Questionable beliefs, he stated, are not the products of irrationality, but rather of flawed rationality.

Kelly et al. (1996) classified some of the cognitive biases under three categories: *selective perception* (we are more likely to notice events that support our beliefs than those that do not), *selective recall* (we are more likely to recall positive instances and forget negative ones), and *selective exposure* (we are more likely to associate with people or news sources that promote our beliefs). All of these effects are much more complex and interesting than the gravitational force exerted by an ordinary natural satellite. Research efforts devoted to understanding these cognitive biases are far more likely to yield productive results than another study of the imagined influence of the Moon on human affairs.

Schaffir (2006) indicated that the proportion of people who believe in a lunar effect is much higher among nurses than among the general population. If selective exposure plays an important role, this trend is unlikely to subside until nursing and medical professionals acquaint themselves with the fascinating cognitive biases that shape our questionable beliefs.

Conclusion

This article examined the claim that hospital admission rates or birth rates are correlated with the phases of the Moon. When one adheres to basic standards of evidence, no such correlation is found. The article described how a number of data collection and analysis shortcomings can lead to erroneous conclusions and how powerful cognitive biases can lead to questionable beliefs.

Accepted for publication September 8, 2014.

The author has no conflicts of interest to disclose.

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