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and health media on patient demand in primary care**

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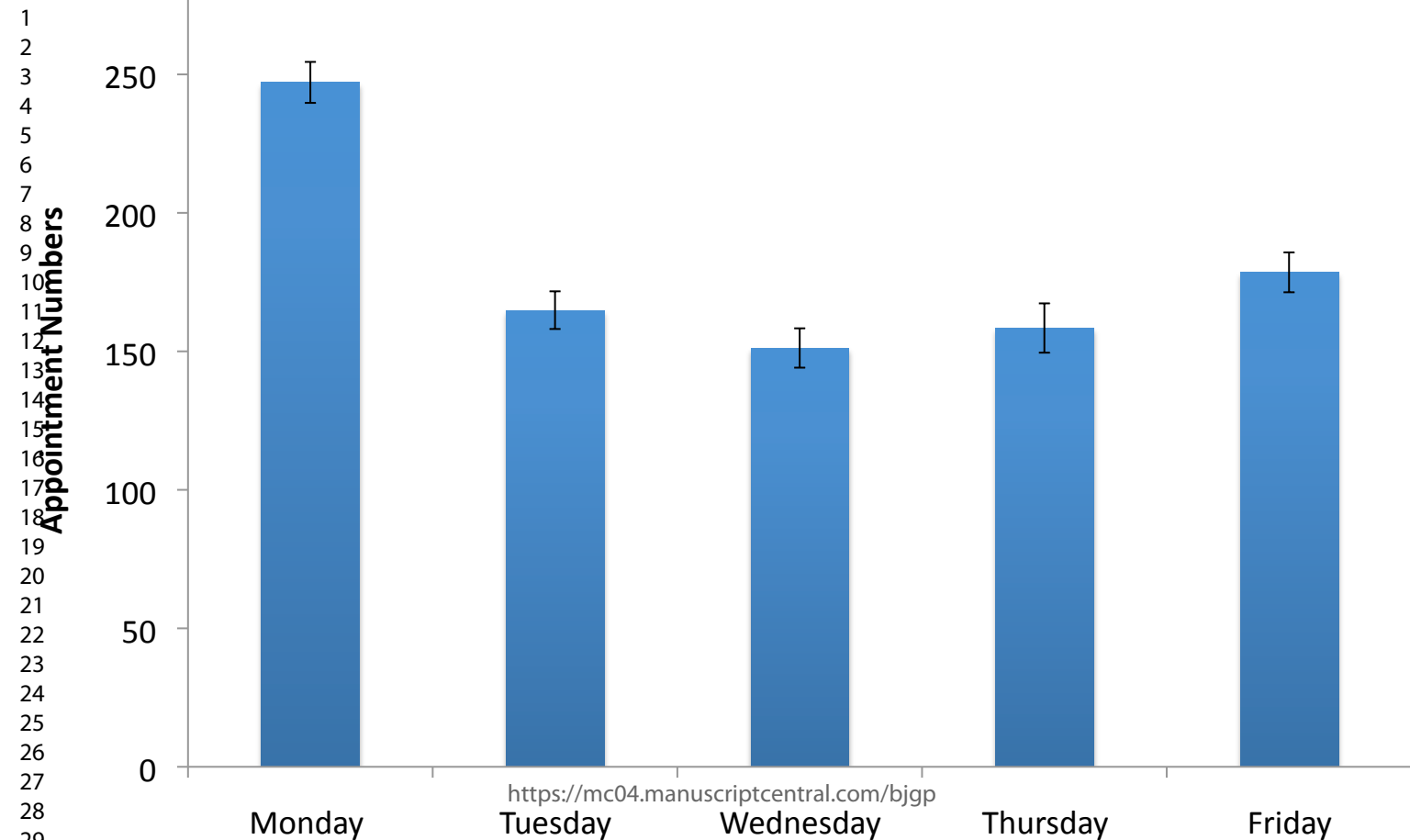
**Exploring the impact of weather variations,
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demand in primary care**

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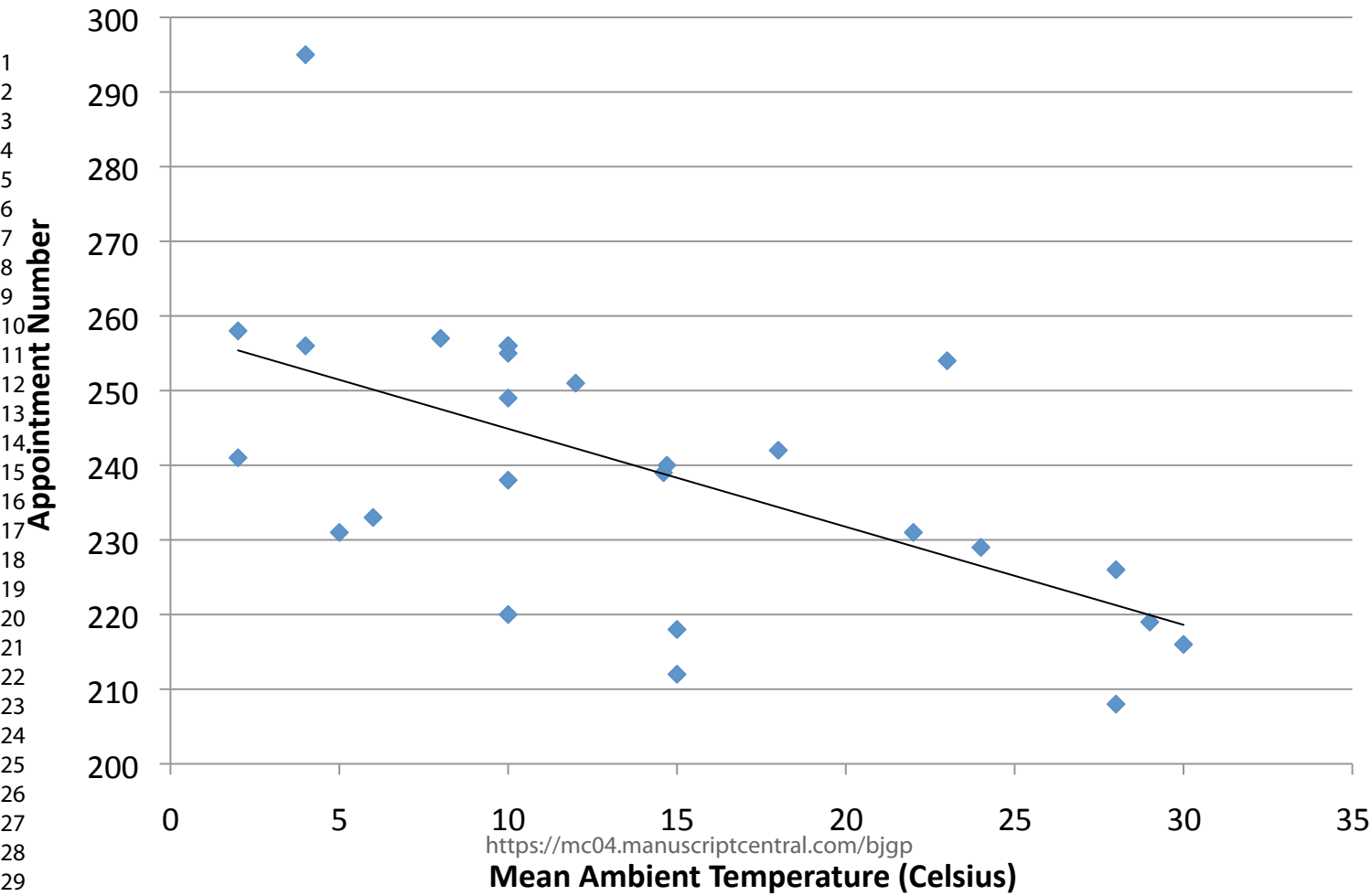
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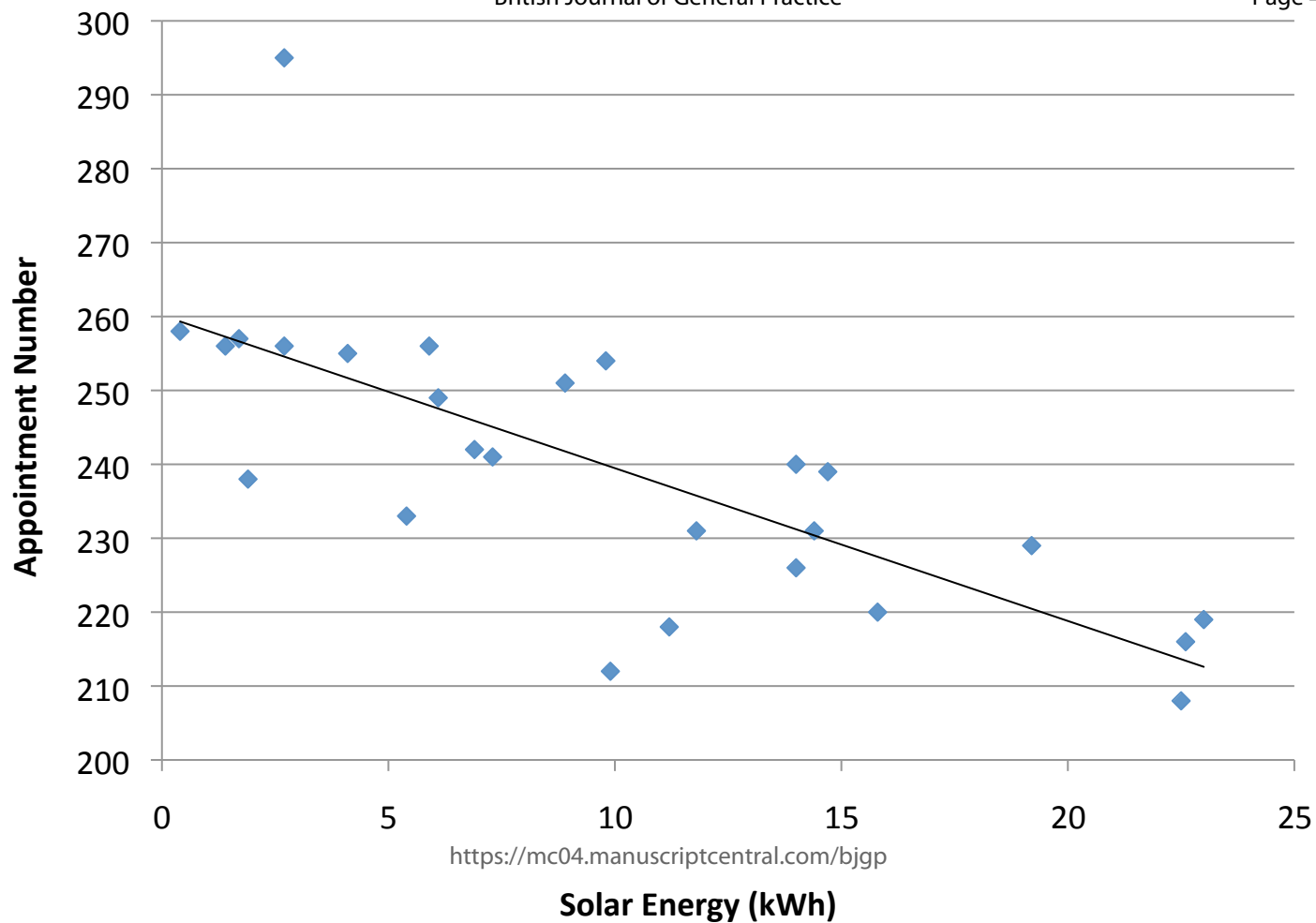
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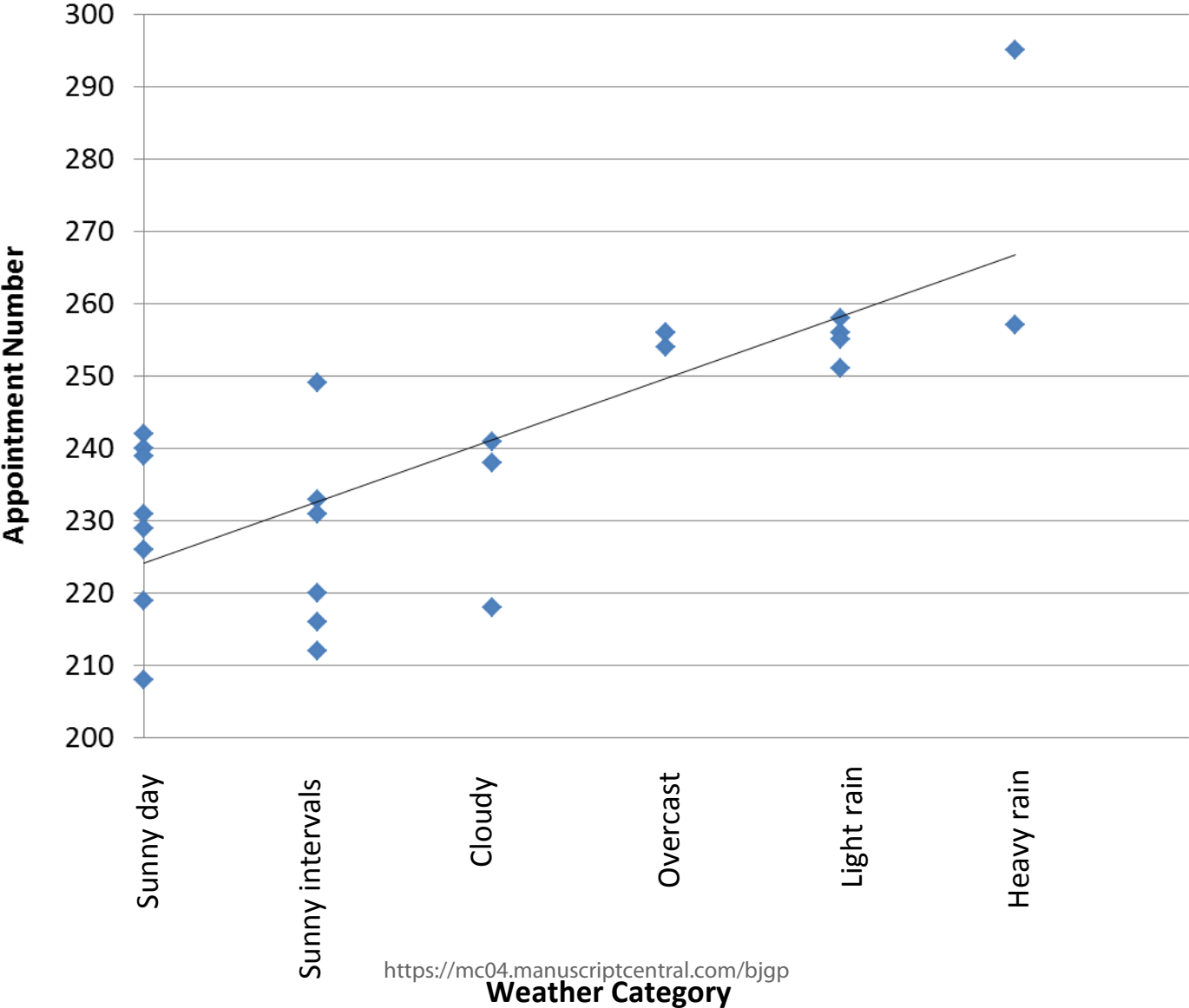
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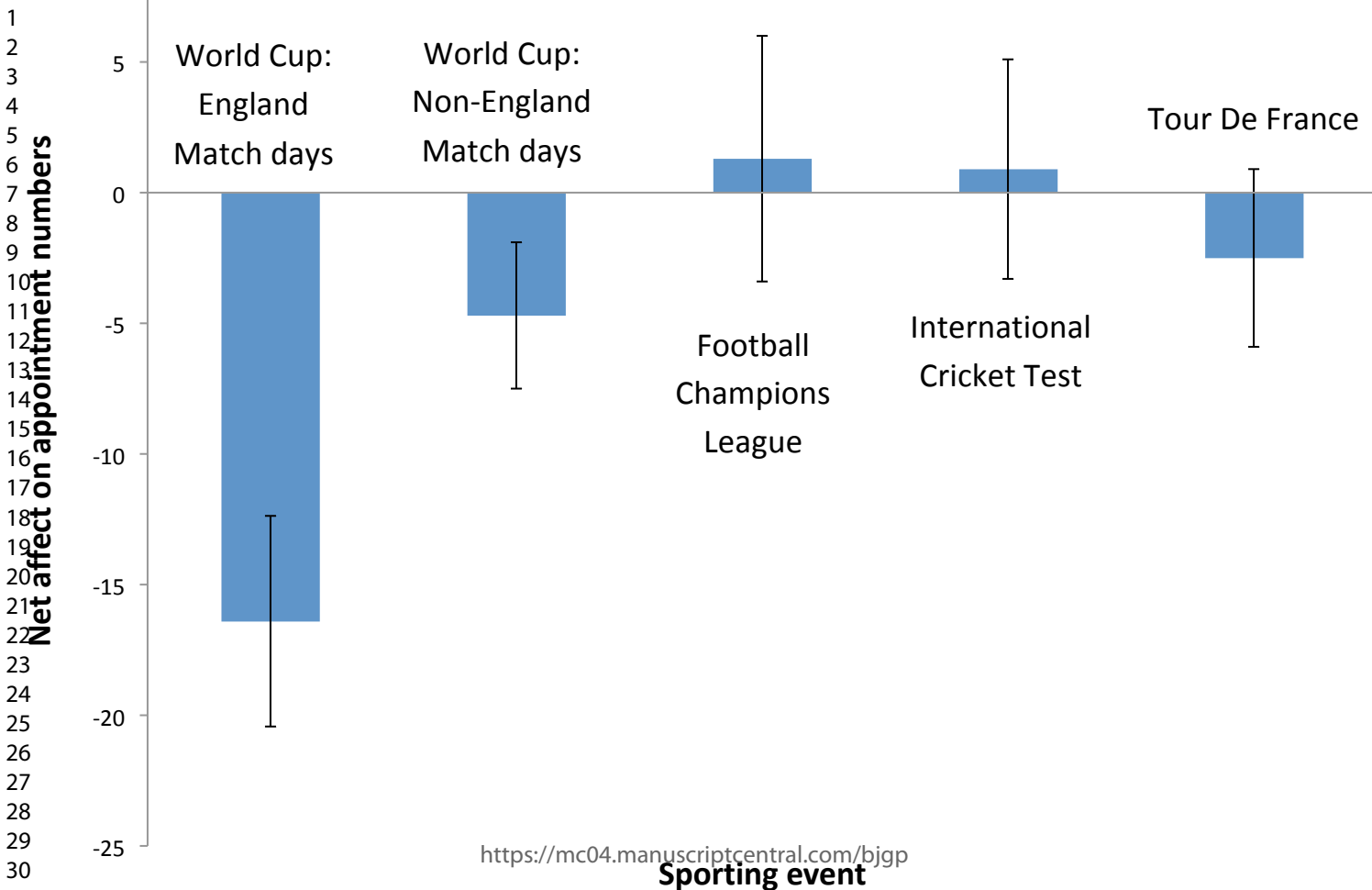


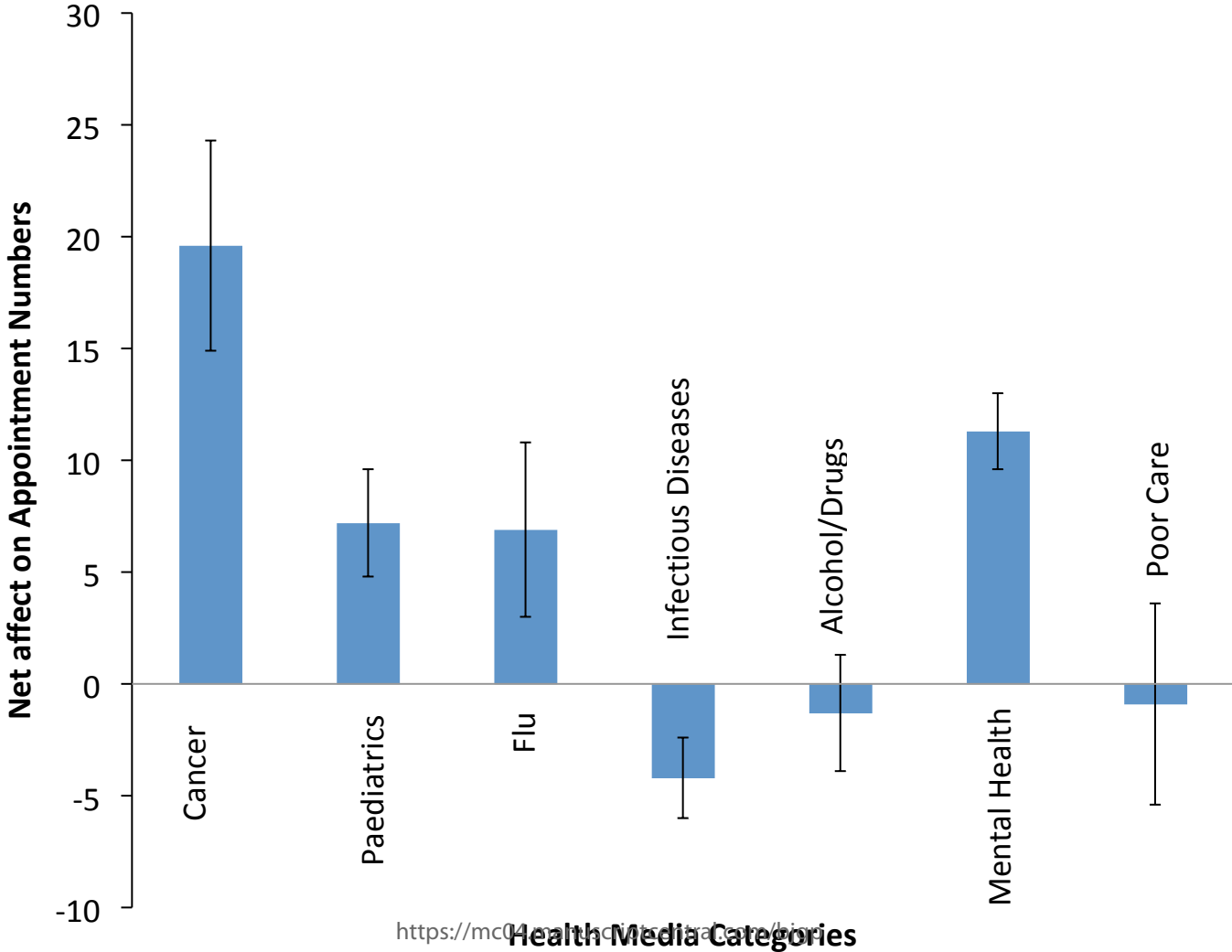
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Weather Category	Group	Pictogram
Snow	6	
Heavy rain (>6mm/12 hours)	5	
Light rain (<=6mm/12 hours)	4	
Overcast	3	
Cloudy	2	
Sunny intervals	1	
Sunny day	0	

Table 1: List of weather categories selected

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Analysing the impact of weather variations, sporting events and health media on patient demand in primary care

Background

Patient demand and consultation numbers are on the rise, placing General Practitioners (GPs) under ever increasing pressure. Over just a 3 year period from 2011 to 2014 there has been an estimated 15% rise in the number of GP appointments (1), with a recent count putting it at 340 million consultations per year in England (2). More intelligent methods of staffing and resource management is essential if primary care In the UK can continue to provide a high quality service. A clear understanding of the factors that impact demand is necessary to allow primary care to allocate resources better, improving patient care and reducing costs.

A number of clinicians have reported patterns in patient demand due the weather and major sporting events (3). However, there has been limited research exploring this potential correlation in local demand. Otsuki et al. showed that in the emergency department, non-trauma & non-serious patient admission numbers positively correlated with mean ambient temperature (4). Hughes et al. found that temperature was the easiest weather variable to predict and likely had the biggest impact on health (5). In their review they explored weather forecasting as a potential public health tool, describing how predominantly extreme weather patterns caused major fluctuations in patient demand. An example being periods of severe cold weather resulting in dramatic increases in fracture rates (6, 7). Aboagye-Sarfo et al. found they were able to formulate forecasting models after analysis of the relevant variables to predict emergency department demand (8).

Similar increases in demand have been reported after major health campaigns or media health coverage. A meta-analysis was preformed exploring the effect of mediated health communication campaigns and concluded that they have a significant impact on patient behavior (9). However, the effect such campaigns have on daily demand is yet to be explored in primary care. Moreover, during our literature search no study was identified exploring the impact of any external variable on daily patient demand in the primary care setting.

One possible rationale for the paucity of research is the method of appointment allocation used. The vast majority of GP surgeries operate a combination of pre-bookable and on the day appointments, allowing them to manage urgent patients promptly incase pre-bookable appointments are full. However, in terms of analysis mapping daily patient demand is problematic using this system, as the majority would have been booked prior to the appointment date. An increasing number of surgeries are adopting a system called *GP direct* (sometimes referred as *Dr First*) where patients call up on the day and are given an initial telephone appointment with a GP for the same day. During this consultation if the GP or patient feels appropriate, often a face-to-face consultation will be undertaken on the same day. One such surgery is Clarendon Lodge Medical Practice. Situated in Royal Leamington Spa, Warwickshire UK it has approximately 13,500 patients and is open from Monday to Friday 08:00 – 18:00. The benefit of *GP direct* for this study is the clear demarcation of daily demand. Furthermore, the system allows any benefits of understanding potential patient demand to be more easily implemented.

Aim

This study aims to explore the impact of a variety of variables on patient demand in primary care. The variables investigated in this study include public holidays, sporting events, health related media and various weather variables. The weather variables analysed comprise of mean ambient temperature (Celsius), precipitation (mm), solar energy (kWh) and weather categories (table 1).

Null hypothesis: There is no relationship between the above variables and patient demand, and whatever variation is present is due to chance.

Method

Data collection

Patient telephone calls at Clarendon Lodge Medical Practice are recorded and documented daily. Data was reviewed retrospectively over a 12 month period between September 2017-18. These were then mapped against the selected variables.

Weather information (weather category, precipitation, and mean ambient temperature) was collected from the Meteorological office website for each working day. The weather category defined the overall daytime weather pattern as described by the Meteorological office for each day and was divided into various discrete quantitative groups (table 1).

Solar energy production was obtained from a local 16-panel 4010W residential installation within 10 miles of the practice address. Total daily production was calculated using the ShinePhone IOS app and displayed in kWh.

Public holiday dates were noted from the UK government website (<https://www.gov.uk/bank-holidays>). Dates for major sporting events were collated through the BBC sports page (www.bbc.com/sport).

Major health related news was obtained using the British Broadcasting Cooperation (BBC) website. Only health stories, which were displayed on the homepage, were deemed 'major' and included in this study. Sampling would occur daily at 07:00.

Data analysis

The data was divided into the different days of the week due to the natural impact of the practice closing over the weekend increasing demand on Mondays and Fridays (figure 1b). Pearson correlation analysis was completed and where found, linear regression undertaken to explore associations between the various independent variables and the daily demand. Further statistical analysis including R^2 , standard error of the estimate and χ^2 -test was preformed with Microsoft Excel for Mac. Tests were two-tailed with P -values < 0.05 deemed statistically significant, and resulted in rejection of the null hypothesis.

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2 *Data exclusion*
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4 On days where the practice reached capacity prior to closing hours only urgent patients
5 would subsequently be booked. The accurate measure of demand used was the number
6 of patient calls requesting appointments, rather than the number of patients booked on that
7 day.
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11 **Results**
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13 44,885 patient appointments were booked during the 12 month study period with an
14 average of 180 per day. Unsurprisingly the demand across the working week had a natural
15 pattern illustrated in figure 1. Mondays had the highest average demand for appointments
16 followed by Fridays. This fluctuation through the week is likely due to patient reporting
17 habits. Patients may delay a number of non-emergency clinical presentations or queries till
18 after the weekend in order to speak to their usual GP on the Monday. A milder Friday
19 spike is also observed likely due to patients looking to access their GP prior to its closure
20 over the weekend. Due to this natural fluctuation in demand through the week, each day
21 was analysed individually to ensure this phenomenon did not impact the results.
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26 *Mean ambient temperature*
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28 Statistically significant changes were found with temperature variations across the working
29 week. Pearson product-moment correlation coefficient demonstrated a negative correlation
30 between temperature and patient demand on each day of the week ($r = -0.43 - -0.60$, $n =$
31 27 , $p = 0.003 - 0.036$). Indicating, lower temperatures produced higher patient numbers,
32 with the inverse true of higher average ambient temperatures. Figure 2 illustrates a linear
33 relationship between patient demand and mean ambient temperature. Therefore, through
34 linear regression a relationship between patient demand and the mean ambient
35 temperature can be elucidated. That relationship is outlined in the following formula.
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38 Patient appointment number (Mondays) = $(-1.2452 \times \text{Mean ambient temperature}) + 256.48$
39 ($P < 0.05$)
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43 *Precipitation*
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45 A Pearson product-moment correlation coefficient was computed to assess the
46 relationship between the precipitation and patient appointment demand. There was a
47 positive correlation between the two variables on both Mondays and Tuesdays. However,
48 this was found to only be statistically significant on Tuesdays ($r = 0.42$, $n = 26$, $p = 0.039$).
49 Overall, there was no correlation between precipitation and patient demand with no
50 discernable pattern identified. Therefore, it appears unlikely that there is a correlating
51 relationship between patient demand and precipitation.
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55 *Solar Energy*
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57 The relationship between solar energy production and patient demand was statistically the
58 strongest out of the weather variables selected, and Monday's results are shown in figure
59 3 ($p < 0.001$). All days except Friday demonstrated a statistical significant relationship
60 indicating that increases in solar energy production correlated with reduce patient demand

($r = -0.74$). The lack of correlation on Fridays may be related to the natural variation seen in demand due to the closure of the surgery on weekends. Patients may have a stronger incentive to book appointments on a Friday regardless of the weather conditions due to the upcoming weekend and therefore lack of access to their GP.

As a result of the strong negative correlation observed from Monday to Thursday, regression analysis was completed for each of these working days.

Weather Category

To facilitate statistical analysis, the qualitative input of weather category was converted into discrete arbitrary quantitative values (table 1). A Pearson product-moment correlation coefficient was preformed to assess the relationship between the varying weather categories and patient demand. The strongest positive correlation was seen on Monday, ($r = 0.76$, $n = 26$, $p = 0.012$) and is illustrated in figure 4. The same positively correlating statistically significant relationship was seen on all weekdays apart from Thursday ($r = 0.39$, $n = 26$, $p = 0.067$). Overall, there was a strong, positive correlation between more settled pleasant weather (sunny and sunny intervals) and reduction in patient demand, while more unsettled weather (light rain and heavy rain) correlated with increases in patient appointment numbers.

Major Sporting Events

The impact of a number of sporting events was explored as shown in figure 5. However, only the football world cup demonstrated statistically significant changes in patient demand ($p < 0.001$). On days with world cup matches, appointment numbers were reduced by an average of 4.7 ± 2.8 . The greatest reduction was seen on days of England games (-16.2 ± 4.03). The effects of other major sporting events were investigated but none were found to be statistically significant.

Major Health Articles

The various major health articles were divided into different medical subjects as shown in figure 6. Health stories would be recorded at 08:00am from the BBC homepage each day. Stories relating to cancer resulted in the largest hikes in demand ($+19.2 \pm 4.7$, $p < 0.001$). This was seen on the first day of the story being recorded on the website homepage. Further statistically significant increases were found with health stories relating to mental health, flu and paediatrics. No significant impact was seen with other subject matters including articles relating to alcohol, drugs and poor care.

Bank Holidays

Bank holidays in the UK are attached to the weekend either on a Monday or Friday. As expected there were increases in patient demand seen on the Tuesday following nearly all the bank holidays during the 12 month study period ($+26.6$ appointments ± 6.7). Remarkably, this was not observed post-Christmas and Boxing Day bank holidays. Instead a marked reduction in appointment numbers was identified despite the GP practice being closed for 4 consecutive days (-23.5 appointments ± 6.9).

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Over-capacity

On days where the practice reached capacity prior to closing hours only urgent patients would subsequently be booked. The remaining patients would then be requested to ring on the following working day where it was found that patient demand rose by an average of 33.1 ± 7.1 $p = 0.048$.

Discussion

Summary

Results from the study have highlighted a number of interesting relationships. Three of the four weather variables explored demonstrated statistically significant correlations with appointment demand. Patient demand was found to increase with lower temperatures. A possible explanation could be that colder weather increases the frequency and severity of a number of conditions. Low ambient temperature has been demonstrated to increase mortality and morbidity predominantly due to cardiovascular and respiratory conditions (10). However, the impact of cold weather tends to be gradual, with the peak effect occurring after 12 days (11), and this study explored daily weather patterns against immediate demand. Alternatively, patients may choose to see their GP on colder days due to concerns about the effects of the cold weather on long-standing conditions or short-term illnesses like upper respiratory tract infections. The relationship between the mean ambient temperature and patient demand was found to be linear. On warmer days patient numbers were significantly reduced. Aside from similar theories relating to how warm temperatures improve various health conditions, patients may choose not to prioritize minor health ailments during periods of good weather. This was supported by the fact during prolonged periods of warm weather, reductions in demand attenuated. Furthermore, when the different weather categories were investigated the more settled weather patterns resulted in reduced patient demand.

Interesting the vast majority of sporting events had no impact on patient demand. However, this was not the case for the football world cup, which resulted in a significant drop in patient demand. The largest reductions were seen during England match days. This potentially supports the theory that a proportion of patients will prioritize watching the football game over arranging a GP appointment. Major health articles also greatly affected the number of patient appointments booked. Topics relating to cancer, mental health, paediatrics and flu demonstrated the greatest impact. Articles relating to cancer in particular showed marked spikes in patient appointment demand, potentially highlighting specific symptoms that the patient was either unaware of or overlooking. Furthermore, they often discuss cases where the cancer was missed or mistreated and often request the patient to contact their GP if they had any concerns, which may have contributed to the increased demand observed.

Strengths and limitations

The meteorological office has 33 distinct weather categories. I summarized them into 7 numerical groups in order to statistically analyse the data (table 1). The arbitrary values applied were consecutive numbers from 0-7. However, weather patterns do not exhibit a

linear relationship. Consequently, the difference between the categories 'sunny day' and 'sunny internals' is unlikely to be comparable to 'heavy rain' and 'snow'. This may well limit the precision of the statistical analysis undertaken. All bar Thursday showed statistically significant variations due to the weather pattern. Colder and wetter weather resulted in increased patient appointments, while warmer, sunnier weather patterns saw a decline in patient numbers. It is important to note that there may well be a natural correlation between the mean ambient temperature and certain weather patterns. Therefore isolating each variables effect on patient demand is problematic. Furthermore, all four weather variables may just be highlighting seasonal variations, essentially telling the same story from four different perspectives.

Precipitation generally failed to demonstrate a significant impact on patient demand. A possible explanation for this outcome is due to the unusually dry spring and summertime experienced in 2018. Alongside 2006 2003 and 1976, 2018 has been confirmed by the meteorological office as being the warmest and 5th driest on record (12). The lack of precipitation data may well have inhibited the assessment of any possible relationship between the two variables.

Numerous sporting events were tracked over the 12 months, and only the football world cup resulted in a significant decline in patient demand. Other events including the Tour de France and International cricket failed to yield similar results. Based on these results one could possibly hypothesize a similar reduction in patient demand during other major international events like the European football championship and the Olympic games, which did not occur during our study period and therefore could not be assessed.

The GP practice investigated implemented their new appointment system at the start of the study period. Despite a long preparation phase to acclimatise patients to the new system, appointment figures may have been affected during the early stages as patients adapt to the new structure.

Comparison with existing literature

Although no research of this kind has been undertaken in primary care, seasonal variations in patient demand have been explored in the emergency department. A Japanese study found that for walk-in and non-trauma patients, emergency department attendance increased significantly with increases in mean ambient temperature (4). This runs counter to the results of this study where increasing temperature resulted in decreasing appointment demand. The weather patterns seen between the two locations are similar. Shiga Prefecture where the emergency department was based had marginally warmer summers. Instead a possible explanation was the types of patient presentations. Although some overlap, primary care and the emergency department will likely deal with different types of medical cases, which could explain the inverse relationship found. Another key difference lies in the booking method. While 'minor' cases in the emergency department predominantly attend by walking in and booking at reception. Patients in this study telephoned to arrange their appointment. This difference may well explain the differing patient behaviour and the inverse relationship seen between the two studies.

Implications for research and practice

This study has helped identify correlations between a number of variables and patient demand in primary care. Exploring other GP practices, which employ the same booking

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system will help appreciate if these associations are transferable as well as comparing patient behaviour between the different practice populations.

Forecasting tools have been grossly underused to assist GP practices to predict future demand. Although forecasting tools based on weather projections are being utilised to manage health on a national level, there is currently little to no exposure on a local level.

Effective use of demand forecasting could allow practices to react quickly to predicted spikes in demand by optimising the deployment of staff to improve patient care and staff workload. With the ever-increasing threat of climate change, understanding how weather impacts patient demand will be crucial to prepare primary care for the future.

Conclusion

This study has shown patient demand in primary care is strongly associated with a number of independent variables. Ranging from specific sporting events, health related articles and weather variables. Furthermore, linear relationships were seen with a number of these independent variables allowing the prospect of a predictive tool to be formulated to estimate future demand. Future research is required at a local level to increase the study period length to at least 4 years. Increasing the data pool will improve the reliability of the results and therefore the validity of the conclusions. Thus enabling further statistical analysis to be preformed.

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