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The association between the lunar cycle and patterns of patient presentation to the emergency department

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THE ASSOCIATION BETWEEN THE LUNAR CYCLE AND PATTERNS OF PATIENT PRESENTATION TO THE EMERGENCY DEPARTMENT.

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of

Master of Science in Medicine in Emergency Medicine.

Johannesburg, 2015

DECLARATION

I, Grant Dudley Futcher, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Medicine (Emergency Medicine) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Signed on 25th day of August 2015

DEDICATION

This work is dedicated to

my children, Charis, Luke and Jarryd,

who have patiently endured their father's choice of medical discipline.

PUBLICATIONS ARISING FROM THIS STUDY

Nil

ABSTRACT

Aim: To determine any association between the lunar synodic or anomalistic months and the nature and volume of emergency department patient consultations and hospital admissions from the emergency department (ED).

Design: A retrospective, descriptive study.

Setting: All South African EDs of a private hospital group.

Patients: All patients consulted from 01 January 2005 to 31 December 2010.

Methods: Data was extracted from monthly records and statistically evaluated, controlling for calendric variables. Lunar variables were modelled with volumes of differing priority of hospital admissions and consultation categories including; trauma, medical, paediatric, work injuries, obstetrics and gynaecology, intentional self harm, sexual assault, dog bites and total ED consultations.

Main Results: No significant differences were found in all anomalistic and most synodic models with the consultation categories. Small but significant increases were found with a small number of synodic models around full moon with some categories, P2 medical, total paediatric consultations and total admissions. Significant decreases in admissions, particulary total admissions, were found around perigee. The effect sizes of all significant lunar associations were smaller than those of the calendric variables.

Conclusions: Most comparisons demonstrated no lunar association. Small but significant associations were demonstrated around full moon with some synodic models. A number of anomalistic admission models demonstrated small but significant decreases in admissions at perigee.

ACKNOWLEDGEMENTS

My family have patiently tolerated me devoting much time on this endeavour. Their support, sacrifice and encouragement is gratefully acknowledged.

I would like to express my appreciation to the following people:

- My supervisor, Prof Mike Wells, for his patience, encouragement and guidance.
- Dr Petra Gaylard for statistical advice, assistance and encouragement.
- Professor Efraim Kramer.
- My wife, Debbie, for support and assistance.
- My daughter, Charis, for editing assistance.
- Sr Nicky Baltsoucos for assistance in accessing the data and in checking and correcting data entries.
- Dr Claire Flanagan, director of the Johannesburg Planetarium.

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NOMENCLATURE

ABBREVIATIONS

A	Apogee
A&E	Accident and emergency (department)
AMI	Acute Myocardial Infarction
BILE	Belief in ‘lunar effect’
ED	Emergency Department/s
FQ	First Quarter
FM	Full Moon
GP	General practice or general practitioner
I	Interphase
ICU	Intensive Care Unit
LC	Lunar Cycle (synodic)
LD	Lunar Day (synodic)
LP	Lunar Phase (Primary)
LQ	Last Quarter
NM	New Moon
MUSS	Medically Unexplained Stroke Symptoms
P	Perigee
P1	Priority 1
P2	Priority 2
P3	Priority 3
PA	Perigee and Apogee

PPC	Predicted patient count(s)
SA	Sexual Assault
SUDEP	Sudden Unexpected Death in Epilepsy

DEFINITIONS

Adult patients:

Patients older than 12 years.

Anomalistic month:

The mean time from one lunar perigee to the next (1)

Apogee (lunar):

The point in the moons orbit at which it moves farthest from Earth (2, 3).

Dog bite (category):

All patient consultations following a dog bite.

First Quarter (FQ):

FQ falls between New Moon and Full Moon and occurs when the Sun and Moon are aligned at right angles to the Earth. FQ occurs when half of the waxing Moon's visible surface becomes illuminated by the Sun as viewed from Earth (4).

Emergency Department (ED):

A dedicated department within a hospital (as in the ED in this study) or other health care facility specializing in the assessment and initial management of a wide spectrum of patient conditions, including those that may be life threatening, in unscheduled presenting patients. The ED is also referred to as an accident and emergency (A&E) department, an emergency room (ER) or a casualty department.

Full Moon (FM):

FM follows First Quarter and occurs as a result of the alignment of the sun and moon at nearly opposite positions in the sky in relation to the earth. The Moon is maximally illuminated by the Sun as viewed from Earth at FM (4).

Intentional Self-Harm (category):

All patient consultations following non-fatal suicide behaviour including both traumatic and non-traumatic events.

Interphase

The interphases are the days between the respective lunar variables and lunar variable periods.

Last Quarter (LQ):

LQ (often called Third Quarter) falls between Full Moon and New Moon and occurs when the sun and moon are aligned at right angles to the Earth. Half of the waning Moon's surface remains illuminated by the Sun as viewed from Earth at LQ (4).

Lunar cycle or **lunation:**

This refers to the synodic month, the period from one New Moon to the next. New Moon marks the first day of the lunar cycle (4).

Lunar day:

A specific day of the synodic lunar cycle that is numerically designated between 1 and 30 counted from NM. The Moons 'age' is the time counted from NM in days.

Lunar Phases (Primary):

New Moon (NM), First Quarter (FQ), Full Moon (FM) and Last Quarter (LQ) occurring in this sequential order are considered to be primary lunar phases (4).

Lunar Phases (intermediate):

These are Waning Crescent, Waxing Gibbous, Waning Gibbous and Waning Crescent and occur following NM, FQ, FM and LQ respectively, between and before the subsequent Primary LP (4).

Lunar variables (anomalistic):

The anomalistic lunar variables are the day of the lunar apogee or perigee (PA0), the day of the apogee or perigee plus and minus 1 (PA1) or 2 (PA2) days and the interphase.

Lunar variable periods (anomalistic):

Each of the respective anomalistic lunar variables comprised anomalistic lunar variable periods:

PA0 comprised the days of perigee (P), apogee (A) and the interphase.

PA1 comprised the day of perigee plus and minus 1 day (P1), the day of apogee plus and minus 1 day (A1) and the interphase.

PA2 comprised the days of perigee plus and minus 2 days (P2), the days of apogee plus and minus 2 days (A2) and the interphase.

Lunar variables (synodic):

The synodic lunar variables are the lunar days, the day of the lunar phase (LP0), the day of the lunar phase plus and minus 1 (LP1) or 2 days (LP2) and the interphase.

Lunar variable periods (synodic):

Each of the respective synodic lunar variables comprised synodicic lunar variable periods:

The lunar days comprised all of the days of the lunar cycle.

LP0 comprised the days of the lunar phases (NM, FQ, FM and LQ) and the interphase.

LP1 comprised the days of the lunar phases plus and minus 1 day (NM1, FQ1, FM1 and LQ1) and the interphase.

LP2 comprised the days of the lunar phases plus and minus 2 days (NM2, FQ2, FM2 and LQ2) and the interphase.

Medical (category):

Consultations resulting from conditions resulting from internal factors or non-trauma related conditions in adults and children including generally recognised medical, surgical, obstetric and gynaecologic conditions.

New Moon:

NM follows the Last Quarter and results from the alignment of the sun, moon and earth in that order. At NM the Moon is between the sun and earth in the sky, resulting in the side of the Moon facing the earth not being illuminated by the Sun as viewed from Earth (4).

Obstetric and gynaecology (category):

All consultations with female patients with diagnoses or conditions of an obstetric or gynaecologic nature. Anecdotally from the clinical exposure of the author the majority of these consultations are for non labour related obstetric and gynaecology conditions.

P1:

The priority of patient condition requiring most urgent attention as defined by the hospital group based on international norms and standards.

P2:

The priority of patient condition requiring intermediate priority and attention as defined by the hospital group based on international norms and standards.

P3:

The priority of patient condition requiring least urgent attention as defined by the hospital group based on international norms and standards.

Paediatric patient (category):

Patients younger than 12 years old.

Perigee (lunar):

The point in the moons orbit at which it moves closest to Earth (2, 3).

Proxigee:

The closest perigee of a calendar year (5).

Public holidays:

Holidays as determined by Act No. 36 of 1994: Public Holidays Act, 1994 of the Republic of South Africa (6) and special holidays as declared (7-9) (see Appendix C).

Quarters or **Lunar Quarter periods:**

Generally defined as the period from the day of the LP to the day before the next.

Sexual assault (category):

All patient consultations of all priorities, sexes and ages presenting to the EDs for care, counselling, anti-retroviral therapy and/or medico-legal examination following an alleged sexual assault.

Sidereal month:

The mean time taken, 27.32166 days, for the moon to orbit the Earth with reference to a fixed star (10).

Synodic month or **Lunation** or **Lunar Month** or **Lunar Cycle:**

The mean time, 29.53059 days, between one New Moon and the next (2, 11).

Syzygy:

Occurs when the Earth, Moon and Sun are in alignment (12).

Trauma (category):

Those consultations as a result of conditions resulting from external factors or injury and including adult, paediatric and work related conditions.

Waning Moon Period:

The period from Full Moon to New Moon with decreasing visible lunar surface and lunar illumination (4, 13).

Waxing Moon Period:

The period from New Moon to Full Moon with increasing visible lunar surface and lunar illumination (4, 14).

Work Injuries (category):

Consultations due to ‘accidents’ defined by Act no. 130 of 1993 of the Republic of South Africa: Compensation for Occupational Injuries and Diseases Act, 1993 and amendments (15, 16).

PREFACE

During a 25-year career in emergency medicine, colleagues, friends and family have often suggested that the unusual nature of events and the number and presentation of cases to the ED was due to the occurrence of Full Moon. I have similarly, often teased colleagues. On checking, I infrequently noted the occurrence of Full Moon but more frequently observed that it was not Full Moon. Undoubtedly, many emergency medicine professionals will have had similar experiences. The literature contains many similar observations and research of colleagues including reports on a belief in a ‘lunar effect’ by colleagues and the lay public. Although neither superstitious nor a believer in astrology, this persistent belief has always intrigued me.

Chapter 1 INTRODUCTION

1.1 Background lunar astronomy

The Moon, planet Earth's only satellite, is close enough to be clearly viewed and dominates our night sky with its prominent cyclical presence. During its lunar cycle maximal visibility and illumination occurs at Full Moon and least at New Moon. The Moon is a unique satellite in our solar system. It was formed, according to current consensus, by the collision of a Mars-sized satellite with Earth approximately 4.5 billion years ago. The rocky mantle of the colliding satellite spun away to form the Moon and the core of this satellite became incorporated into a consequentially larger Earth. Within our solar system satellites of other planets are either captured satellites or formed by accretion (2, 17). The Moon is further unique in that it is the largest satellite in our solar system relative to its planet and most likely left the Earth with an axial tilt and 24 hour rotation period following its formation (2).

The Moon and Earth, rotating anticlockwise on their own axes also orbit the Earth and the Sun respectively in an anticlockwise manner as viewed from above the North Pole. The sidereal month is the mean time taken, 27.321 66 days, for the moon to orbit the Earth with reference to a fixed star and also corresponds to the time taken for a single lunar axial rotation (2, 10, 17). The lunar synodic month, lunar cycle or lunation is 29.530 6 days in duration and is the time lapsed between successive new moons. The lunar synodic month is more than 2 days longer than

the sidereal month since the Earth continues to move on its orbit around the sun and delays the illuminated portion of the moon visible from Earth (2).

The synodic lunar cycle comprises four primary lunar phases, New Moon (NM), First Quarter (FQ), Full Moon (FM) and Last Quarter (LQ). The lunar cycle progresses from New Moon with the least illumination of the lunar surface as viewed from Earth, through Full Moon with maximal lunar illumination, to the next New Moon (4). The period from New Moon to Full Moon is referred to as the Waxing Moon, which is characterised by increasing lunar illumination, and that between the Full and next New Moon as the Waning Moon, which is characterised by decreasing lunar illumination. Between the primary lunar phases are the intermediate lunar phases of Waxing Crescent, Waxing Gibbous, Waning Gibbous and Waning Crescent, which occur following NM, FQ, FM and LQ respectively (4). Full Moon and New Moon occur when the Earth, Moon and Sun are aligned in a straight line (syzygy). Full Moon occurs when the Sun maximally illuminates the surface of the Moon as viewed from Earth as a result of the three bodies being aligned in the order Sun, Earth and Moon. New Moon occurs when the Moon is least illuminated by the Sun as viewed from the Earth and occurs when these bodies are aligned in the order of Sun, Moon and Earth (4, 12).

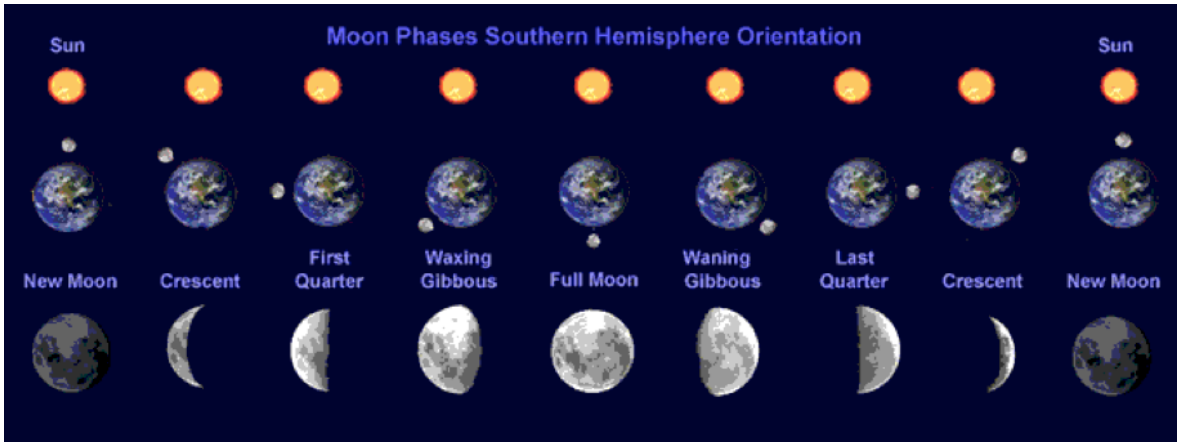

Figure 1.1 Moon Phases as seen from the Southern Hemishere.
Lunar illumination and the sun-earth-moon orientation during the lunar cycle is illustrated above. The lunar image as viewed in northern hemisphere would be the above southern hemisphere images inverted 180° on the vertical axis (18).
Graphic courtesy of Paul Brick of Astroplot, used with permission.

The Moon's orbit around Earth is slightly elliptical resulting in the Earth-Moon distance varying from 363 000 to 406 000 km (average 384 000 km). The terms Perigee and Apogee are used to describe when the moon is at its closest and farthest points from the Earth respectively, on its elliptical journey. The distances at each perigee and apogee are not constant (2, 3). The anomalistic month is the mean time lapsed from one perigee to the next and is 27.55464 days in length, which is 5.5 hours longer than the sidereal month (1). The Moon looms larger and lunar gravitational force is greater at perigee than at apogee. The gravitational force exerted by the Moon and Sun on the Earth results in the phenomenon of the oceanic tides and is also increased at NM, FM and at perigee (19, 20).



Figure 1.2 Full Moon viewed from Earth at Perigee and Apogee.
Photo courtesy of Pedro Ré (21), used with permission.

1.2 Lunar influence on human culture and belief

The moon has long held social, religious, cultural and scientific importance in human affairs. It has captivated almost all cultures, societies and civilisations across the world throughout the ages, from antiquity to the present era. This pervasive fascination with the moon is reflected by veneration and deification of the moon, innumerable lunar stories, fables, myths, folklore and legends, and the belief in a 'lunar effect' on many facets of existence (22-27).

Calendric association with the moon (and sun) in a number of forms has resulted in religious and cultural festivals being linked to the lunar cycle. The observances by Christians of Easter (28, 29), the ancient Hebrew calendar and festivals (30) and the Muslim calendar and festivals (30) amongst others are linked to the lunar cycle (31). Elen Hawke notes in her book, *Praise to the Moon: Magic & Myth of the Lunar Cycle*, that 'working with the moon's cycle is at the heart of witchcraft' (22). Astrology, in current practice and in profusion on the Internet, continues to

reinforce belief in cosmic (including lunar) influence on human existence. It influences behavioural adjustments for success to the extent that the former president of the United States of America, Ronald Reagan, allegedly allowed his wife, Nancy, to determine his schedule on astrological advice (32, 33).

Despite widespread belief in human to animal transformation (34-41) puportedly timed with FM (42), two clinical literature reviews (36, 37) uncovered only a single anecdote which ironically reported the resolution of a patients relapsed delusional wolf-ike behaviour at FM (40).

The English noun 'lunatic' (which is not in current clinical use) can be used to describe "a person who is mentally ill" or "an extremely foolish or eccentric person". It is derived from the Old French 'lunatique' which was derived from the late-Latin term 'lunaticus', which itself was derived from the Latin word 'luna' meaning moon (and the name of the Roman god of the moon, Luna (43)), and stems "from the belief that changes of the moon caused intermittent insanity" (44, 45). The original meaning of the term 'lunaticus' appeared to be reserved mainly for use in epilepsy until the fourth and fifth centuries when it began to change meaning to include other neurological and psychiatric diseases (43). The term 'lunatic' appears to have entered use in the English language at the end of the 14th century and came into widespread use in the English language between the 16th and 17th centuries.

The literature of this time, notably that of William Shakespeare, as a result of this acceptance of the moons role in mental illness contains numerous such references (43, 46).

Shakespeares *Othello,* for example, after murdering his wife Desmodena blames the moon for his actions stating, “it is the very error of the moon, she comes more near the earth than she was wont, and makes men mad” (47). The 1621 English play *The Witch of Edmonton* by William Rowley, Thomas Dekker and John Ford opines “when the moon's in the full, then wit's in the wane” (48). The word ‘moonstruck’ came into popular English use in the 17th century as a result of popular belief in the negative influence of the moon on the human mental state (43). John Milton in *Paradise Lost* refers to “moping melancholy and moon-struck madness” (43, 49). A number of European languages continue to use words derived from the term ‘lunaticus’ (43).

1.3 Medical historical perspective

The belief by medical professionals of many diverse societies and cultures in the influence of the moon on human behaviour and its role in human wellbeing and healing is evident over many centuries. Hippocrates (c 460-377 BC), the ancient Greek physician, often referred to as the father of medicine, was probably one of the first physicians to document lunar belief when he wrote that “no physician should be entrusted with the treatment of disease who was ignorant of the science of astronomy” (50, 51). He is further reputed to have stated that one who is “seized with terror and fright, and madness during the night” is due to being visited by Hecate, the goddess of the moon (46, 52).

Ancient writers, icons of science and medicine, besides Hippocrates, including Aristotle, Pliny the Elder, Paracelsus, Empedocles, Celsus, Plutarch, Galen,

Berzelius and Darwin all reputedly held belief in a ‘lunar effect’ on man in one or other aspect including mental illness and abberent human behaviour, epilepsy, migraine and menstruation (46, 50, 53).

The *Su Wen*, an ancient Chinese medical text, confirms ancient Chinese acceptance of a lunar (and wider celestial) role in human well-being and health. Golding in *The Complete Stems and Branches*, quotes a translation of the *Su Wen*, “The physician should await the right moments regarding the movements of the sun, the moon, the stars, and the energy of the four seasons and the eight seasonal dates, and as soon as the right moment arrives relative to the stable state of energy, acupuncture treatment should begin” (54).

1.4 Introduction to the “lunar effect

A number of terms have been given to the notion that lunar phases, most notably full moon, exert an effect on human behaviour and biology. Shapiro and co-authors (1970)[a], refer to the ‘Transylvanian effect’ and ‘Transylvanian hypothesis’, which relate to the notion that moon phase and patient behaviour are related (42). Wilson and Tobacyk (1990) define a ‘Lunar hypothesis’ as “the notion that lunar phases can directly affect human behaviour” (55). “Lunar effect” is the most commonly utilised term to describe the concept of correlation between the lunar cycle and human behaviour and biology or as Iosif and Ballon put it “ that more ‘lunacy’ occurs during certain phases of the moon” (50).

[a] Dates of publications are documented to highlight historical progression.

Modern medical literature into “lunar effect” include studies considering:

1. The extent of and reasons for the common belief in lunar effects,
2. Explanations for any possible lunar effect in medical practice and
3. Whether an effect exists on human behaviour and biology in medical practice.

1.5 Studies into the belief in a ”lunar effect”

Laycock in an 1843 review in the Lancet wrote: “the opinions hitherto held by scientific men on the validity of the doctrine of lunar influence have been remarkably discordant” but that the popular opinion of the time considered “that epilepsy, insanity and asthma, recur at intervals regulated by the moon” (56). The belief in a lunar effect is pervasive, regardless of profession, but some occupations have greater belief than others (42, 57-59). The belief as Oliven stated in 1943, “dates from ancient times and has survived rather obstinately” (46). Undoubtedly the media, Internet, and lay literature, often with significant bias, have played a role in perpetuating this belief, despite studies generally yielding contradictory results (50, 60, 61).

Numerous studies have been conducted to establish the extent of the belief in a lunar effect. Angus (1973) found that 50% of 74 obstetric nurses believed moon phases influenced delivery and 74% of 86 psychiatric nurses expressed belief in a ‘lunar effect’ on mental illness. Of the psychiatric nurse believers 83% considered full moon to be the important phase (62). Russell and Dua (1983) found that 45% of a group of 502 Canadian psychology students believed in the influence of lunar

phases on human behaviour. Furthermore they found that despite evidence of belief by 36.5% of 85 male ice hockey spectators at the 12 team 426 game 1978/9 Western Hockey League season, analysis of the league revealed no significant correlation between lunar phase and aggression on the rink (63).

A nine-item scale, the Belief in Lunar Effect (BILE) scale, was devised by Rotton and Kelly (1985) to more efficiently assess the 'belief in lunar effect' (64) and others have modified and used this scale to assess this belief (49, 55, 65, 66). Rotton and Kelly's 1985 study (64), found that 46% of 165 university students held the belief that people 'act strangely' during full moon. In a BILE scale validation study with Elortegui (1986) they found that a group of 33 police officers expressed greater belief than either of a group of 36 psychiatric personnel or 60 pedestrians[b] (66). Danzl (1987) in a small modified BILE scale study of 25 ED physicians and 25 ED nurses reported that 80% of the nurses and 60% of the physicians expressed belief. In addition, he found that 92% of the nurses felt that they should receive 'lunar pay differentials' due to increased stress. He, tongue-in-cheek, suggested a series of entertaining ED strategy options to deal with this belief (49). Wilson and Tobacyk (1990) in utilising the BILE scale found that a group of 87 crisis centre workers scored significantly greater on the BILE scale than a control group of 102 students (55).

In a non-BILE scale based questionnaire by Vance (1995), 43% of the study group of 325 people held a personal belief that human behaviour was altered by lunar phenomena. Mental health professionals (clinical psychologists, social workers,

[b] A control group.

nurses and nurses' aides) held this belief most strongly (67). In assessing a group of 49 nurses working in different fields utilising Rotton and Kelly's BILE scale Snelson (2004) found that 51% indicated a BILE and that this belief was most strongly held by A&E and psychiatric ward nurses than community based psychiatric nurses (65). Mandell and co-authors (2005) and Schaffir (2006) respectively reported 69% of 200 perioperative nurses and 68% of 38 obstetric nurses expressed belief that Full Moon worsens workload and stress and influences the onset labour respectively (58, 68). Finally, Scuffy (2011) demonstrated in a BILE scale study that emergency room professional personel more strongly believed that "the 'crazies' come out when the moon is full" than staff working at a juvenile facility (69).

On a lighter note, the published responses in the August 1992 Canadian Medical Association Journal to the Aprils fool hoax article by Davis (70) on the 'Psychopharmacology of Lycanthropy' reflect little belief in a lunar effect and much mirth (71-74).

Studies reporting that groups working in very stressful environments (obstetric, perioperative, psychiatric nurses and other mental health professionals, policemen, A&E staff and crisis centre workers) express greater belief in a lunar effect may reflect a coping mechanism for the unpredictability in the work environment and the associated stress experienced (49, 55, 67). A correlation between the BILE scale and belief in paranormal phenomena has been demonstrated (64, 75). Despite expressing belief in a lunar effect, some study

subjects are unable to correctly identify the lunar phase at a point in time (62, 65). Ultimately, belief may merely be as a result of a self-fulfilling prophecy.

1.6 Significance of the study

This study is significant in that this is the first such study conducted in South African emergency departments and represents the first time that an array of emergency department presenting categories, combining condition and priority were studied. The data included larger patient volumes than most previous international studies. The topic is of importance mostly from an academic point of view to answer the question of whether a lunar effect exists. If such an effect is demonstrated, then to establish whether it is of such a magnitude as to change approaches to staffing and hospital occupancy.

1.7 Aim and objectives

1.7.1 Aim

To determine whether the number and nature of emergency department consultations and admissions over a six-year period at a South African private hospital group's emergency departments were associated with synodic lunar phases or apogee and perigee of the anomalistic month.

1.7.2 Objectives

1. To control for any calendric influence on the evaluation of any lunar effect
2. To ascertain whether a synodic or anomalistic 'lunar effect' or association existed with respect to the:
    - volume and nature of patients presenting to the ED
    - volume and/or nature of patients in a number of patient categories presenting to the ED
    - volume and nature of patients admitted to hospital from the ED.

1.8 Summary

The moon creates tidal movement and nocturnal illumination, influences human religion, culture, society, language and a belief in a lunar effect on human endeavour, behaviour and biology. But is the lunar synodic cycle and anomalistic month associated with a varying nature and volume of emergency department patient presentations and admissions?

Chapter 2 LITERATURE REVIEW

2.1 Studies into a synodic 'lunar effect' on human behaviour and biology

Such is the belief and interest in the possibility that a lunar effect exists, that a wide variety of studies have been conducted in numerous countries into a large array of areas of human behaviour, biology and endeavour. Findings of research into a lunar effect are often contradictory.

2.1.1 Emergencies and the emergency department

Remarkably, despite belief in a lunar effect by some emergency staff, no studies were found reporting a correlation between any period of the lunar cycles and total patient volumes in the emergency department. Two studies were found reporting no correlation. Thompson and Adams in 1996 evaluated 150999 emergency department consultations in Chicago over a four-year period (76). This retrospective analysis of hospital electronic records utilizing ANOVA methods, reported that there was no association between FM and consultation volumes. Exadactylos and co-authors (2001) analyzed data on 14514 patient consultations over 8 months at a Berne, Switzerland emergency department and found no increased volumes at FM in a number of categories including, medical, non trauma related surgical emergencies, mild and moderate trauma, multiple injured patients and attempted suicides (77).

Nothing was found in the literature specifically investigating volumes of emergency department consultations of varying patient severity and the lunar cycles.

Patient consultations as a result of specific conditions and categories will be discussed in subsequent sections. These contribute to the total patient consultation volumes in the ED.

2.1.2 Trauma

A number of studies have examined whether there is a lunar effect on trauma occurences. A few studies reported significant results. Templer and co-authors (1982) reviewing California Highway Patrol data on 291939 vehicle accidents in the year 1980 found increases at NM and FM (78). Kelly and Rotton (1983) on review of the data demonstrated that these claims were statistically flawed and failed to consider confounding effects between the days of the week and lunar phases over the short one-year study (79). Nijsten and Willemsen (1991) analysed 29085 Groningen, Netherlands trauma patients consulted over a three-year period and 930 seriously injured patients assisted over a five-year period (59). This study reported that statistically fewer trauma patients were consulted over FM and no effect was identified with regard to the more seriously injured patients. Sitar (1994) analysed 60142 traffic accidents in the former Monrovia region over five non-consecutive years finding two significant increases in trauma presentations, firstly on the second and third days following NM and the second from the day before FM to the second day following (80). Stomp and co-authors (2009), retrospectively analysed 36 years of data from Groningen, Netherlands involving 354150 injured patients using Poisson regression spline fitting analysis. They found a lower incidence of trauma at FM than NM. They postulated that this decrease is due to better night-time visibility at FM (81).

In other studies no significant results were found. Exadactylos and co-authors (2001) as mentioned previously, found no increased volumes at FM in a number of trauma categories including mild and moderate trauma and multiple injured patients (77). Zargar and co-authors (2004) reviewed 54457 trauma cases over 12 months presenting to Tehran emergency departments and found no association between FM and the volumes of injured patients or the severity of their injuries (82). Burrell and co-authors (1994) reviewed 8760 trauma consultations over a three-year period presenting to USA trauma centres and found no correlation between lunar cycle and volumes of trauma consultations (83). Coates and co-authors (1989) analyzing 1444 trauma patient consultations at a USA emergency department over a one-year period found no FM effect in relation to trauma volumes or severity (84). In further trauma studies no correlation was found with respect to vehicle traffic accidents (59, 85-87) and falls by hospitalised adult patients (88). In a retrospective study of 11134 emergency cases managed by a prehospital emergency service in Graz, Austria over a six-year period, Wolbank and co-authors (2003) found no correlation with the synodic (or anomalistic) lunar cycles (89). Stomp and co-authors (2011), in a review of trauma presentations, suggested that if there is lunar influence on trauma, it is small (90).

2.1.3 Medical (non trauma)

Little has been researched into a possible lunar effect on the nature and volume of general medical consultations in the ED. Wolbank and co-authors (2003) in a study described earlier found no correlation between the synodic (or anomalistic) lunar cycles and life threatening cardiac, pulmonary and neurological emergency

cases managed by a prehospital emergency service in Graz, Austria (89). Likewise, Exadactylos and co-authors in their emergency department study found no correlation between FM and medical consultations (77).

From a priority perspective, for example, Alves and co-authors (2003) in a retrospective study of 6827 New Jersey, USA patients over 11-years undergoing cardiopulmonary resuscitation found no significant difference in the occurrence of such resuscitation during FM days but a lesser incidence during NM and other days (91). Eisenburger and co-authors (2003) in Vienna, however, found no significant association with the lunar cycle in evaluating 368 cardiac arrests of cardiac origin and 872 myocardial infarctions over a seven-year period (61).

Further studies on a number of specific medical (non trauma) conditions of varying severity that would most likely contribute to emergency department medical consultation volumes have yielded differing and often contradictory findings. Table 2.1 presents these medical studies divided into those that demonstrated a significant lunar effect and those that have not.

Table 2.1 Medical studies

Effect	No effect
Non-epileptic seizures - increased around FM. Seizures greater on dark than brighter nights **(92)**	
Status epilepticus admissions to ICU. Peak 3 days after NM and vary greatly across LC **(93)**	
Seizures clustered around FM. **(94)**	
Psychogenic non-epileptic seizures. Increased at FM and epileptic seizures in LQ **(95)**	
Sudden unexpected death in epilepsy (SUDEP) in children. Highest incidence at FM (70%) **(96)**	Sudden unexpected death in epilepsy (SUDEP) in adults (97)
Intracranial aneurysm rupture. Increased at NM **(98)**	Aneurysmal SAH (99)
Abdominal aortic aneurysm rupture. Higher during waxing moon (FQ) period **(100)**	
Acute coronary syndrome. Increased incidence on NM days **(101)**	Acute Myocardial Infarction (102)
Attacks of paroxysmal atrial fibrillation. Decreased at FM **(103)**	
Sudden cardiovascular death. Maximal during FQ & LQ **(104)**	
Acute myocardial infarction incidence. Maximal around NM and least around FM **(105)**	
Renal colic incidence. Greatest around FM and least at NM **(106)**	ED renal colic admissions (107)
Urinary retention incidence. Higher during NM **(108)**	Renal lithiasis. (109)
Urological emergencies. Increase over FM and decrease over NM **(110)**	Oral and maxillofacial emergencies (111)
Spontaneous pneumothorax incidence. Peaks one week before & after NM **(112)**	
Acute infectious diarrhoea. Less during NM, FQ, FM & LQ **(113)**	
Admissions for gastrointestinal bleeding. Increased during FM, esp. men & patients with variceal haemorrhage **(114)**	Hospital admissions for epistaxis (115)
	Post-tonsillectomy haemorrhages (116)
	Blood loss and emergency operations (117)
Gout attacks. Cycling noted with highest peaks at NM and FM. Peaks at each of the quarters **(118)**	Post-operative haemorrhage after thyroid surgery (119)
Requests for thyroid outpatient clinic follow up appointments peak 3 days after FM & new appointments 5 days after FM **(120)**	Post-operative nausea & vomiting (121)
GP consultations. A small increase 6 days after FM **(122)**	
Paediatric mortality. Increased male deaths at FQ, FM and NM **(123)**	Deaths (124)

It is not possible to extrapolate the results on specific medical conditions to that of categories of general medical conditions even though they would form part of the various categories in this research.

2.1.4 Paediatrics

No literature regarding general paediatric ED presentation in relation to the synodic lunar cycle was found. Specific non-ED studies on the paediatric population and lunar effect were found. Sobel and co-authors reviewing 3 204 child psychiatric emergency contacts over a five year period (1988 to 1992) with a rural community health centre in Vermont, USA found no association with the day of FM (125). Russel and Bernal, in examining 300 home observations on 76 boys aged five to seven years old collected over a two-year period found no association of desirable or undesirable behaviour with the three-day period of and around NM or FM compared with the interphase (126). Two studies demonstrated statistically significant lunar effects. The first, reviewing 10 events of sudden unexpected death in epilepsy (SUDEP) in children over an eight and a half year period (January 2000 to June 2008) at a Sao Paulo, Brazil hospital reported the highest incidence (70%) over the 3 day period of and around FM (96). The second reviewing 2 003 paediatric deaths over a six-year period (1991 to 1996) in a Mexico City hospital curiously found only male mortality to be increased over the three days of and around all of the primary lunar phases with the exception of the LQ (123). Kennedy and co-authors in a study of 6 770 paediatric orthopedic injuries found that the lunar phase had no effect on the rate of these injuries (127).

2.1.5 Work injury

Similarly, few reports appear in the literature on a possible association of lunar phase and cycle with work injuries. A single work-injury study, which included motor vehicle injuries, published in 1982 examined 172 155 work injuries reported to the Californian Department of Labour Statistics during the first six months of 1980 (78). The three-day FM and NM phases defined respectively as the day of FM or NM plus the days before and after were compared to the intervening days (the interphase). More injuries were reported during the nights of the FM and NM phases than the intervening nights (the interphase) but not during the daylight hours of these phases. A subsequent reevaluation of this study (Rotton & Kelly, 1983) found that these findings were statistically flawed and failed to consider the confounding effects between lunar phases and days of the week over the short six month study period. An unpublished study on 500 000 industrial accidents in Austria between 2000 and 2004 (128, 129) was reported to demonstrate no relationship to FM and a smaller study of 3 924 consecutive work accidents from Sao Paulo, Brazil (130) in 1982 demonstrated no significant association with the primary lunar phases. Conversely, a study on work absenteeism demonstrated a significant but very slight decrease at FM (131).

2.1.6 Obstetrics and Gynaecology

No studies were found investigating a possible lunar effect on general O&G conditions presenting to the ED. Studies on potential lunar effects on the female patient are focused on the menstrual cycle and obstetric events. Despite

widespread belief in a lunar influence on menstruation and Greek and Latin etymological connections between menses, menstruation, month and moon (132-135), little evidence exists for a lunar menstrual effect. The few studies reporting a lunar cycle correlation to menstruation have demonstrated contradictory results. One study reported menstrual correlation to NM (136) while two other studies demonstrated correlation to the light half of the lunar cycle i.e. around FM (137, 138). Amongst studies reporting no menstrual correlation to the lunar cycle (139, 140) is a study on the Dogon (141), a Malian tribe who live without electric lighting and are thus more likely subject to the influence of cyclical lunar illumination.

Studies into conception in assisted reproduction (142), labour and delivery (spontaneous and complicated) (143-150), births (124, 151-153), birth complications, neonatal outcome, stillbirths (154) and gender (155) from a number of countries demonstrated no correlation with the synodic lunar cycle. Again, the few studies supporting a lunar correlation reported contradictory findings. Two studies on spontaneous labour demonstrated increases around FM in multiparae and plurigravidae (156, 157). Stern,however on controlling for barometric pressure found that the results were not significant (157). A large study demonstrated increased births between LQ and NM (158) and another increased births at LQ (159).

2.1.7 Aberrant behaviour including sexual assault and intentional self-harm

Understandably, much research has been done into aberrant human behaviour (for lack of a better expression) to determine whether “lunar lunacy” truly exists.

Studies into facets of aberrant behaviour have included psychiatric presentations of anxiety, depression, intentional self-harm (suicide and non fatal suicide behaviour), aggression and crime, including sexual assault.

2.1.7.1 Sexual assault (including homicide, violence, aggression and crime)

A number of studies have been undertaken attempting to determine whether any "lunar lunacy" exists with respect to the spectrum of crime, aggressive behaviour, assault and sexual assault. Two studies were found examining sexual assault. The first, Tasso and Miller (1976) examined 34 318 criminal offenses in nine categories including domestic violence, assault and sexual assault and found that all categories occurred more frequently during the period of FM +/- 3 days studied than at other times of the lunar cycle (160). The second, a South African study by Snoyman and Holdstock (1980) examined 2 344 crisis incidents of the patients contacting a Johannesburg crisis clinic in 1976 (161). They found that sexual assault incidents increased during the waxing moon and that crisis incidents had positive correlation to FM every second month. Considering that the single year in the study, 1976, was a year of great turmoil in South Africa and that the results were so unusual these results should be considered with caution. Table 2.2 summarizes the spectrum of studies on crime, assault and aggressive behaviour that demonstrated both an effect and no effect. It is evident that significant effects demonstrated by different studies occur most commonly at NM and FM.

Table 2.2 Homicide, violence, aggression and crime

Effect	No effect
Homicides. Significant groupings around FM and NM (162)	Homicides (163, 164)
Homicides and aggravated assaults. Significant clustering around FM (165)	Aggravated assault (battery) (166)
	Victims of aggression seen in ED (167)
	Domestic violence incident rates (168)
Crime. Increased incidence at FM (169)	Reported crime (170)
	Calls for police assistance (171)
Violent & acute behavioural disturbances in ED. Increased during FM (172)	Psychiatric inpatient violence & aggression (173)
Psychiatric emergency hospital visits. Severity of illness & aggressive behaviours increased around NM (174)	Acting out behaviour – psychiatric hospital (42, 175)

2.1.7.2 Intentional self-harm and related studies

Intentional self-harm, the compulsion to harm oneself, could be considered as the most notable form of lunar lunacy. Studies found are again inconsistent in their findings. Lieber (1978) found clustering of suicides in and around FM (165) and Buckley and co-authors, similarly, found greater self-poisoning events in males at this time but found increases at NM in females (176). Yvonneau (1996) found fewer deaths at FM than FQ (177) while Jones and Jones (1979) found increases at NM rather than FM (178). Two studies found lunar correlations with suicide attempts. Taylor and Diespecker (1972) found increases at FQ and decreases at LQ (179) while Oderda and Klein-Schwartz (1983) found increased suicide attempts at NM (180).

Conversely, a number of studies found no lunar correlation to suicides (52, 164, 181-186) or parasuicides (65, 187-190).

2.1.7.3 Anxiety, depression and other psychiatric studies

A spectrum of psychiatric illness, including anxiety and depression, which are often co-morbidities of intentional self-harm, have been studied attempting to determine whether a lunar association exists or not. Unsuprisingly, these findings too have been varied as is usual for such research. Table 2.4 summarises these studies with and without identified lunar correlations.

Table 2.3 Anxiety, depression and other psychiatric studies

Effect	No effect
Medically unexplained stroke symptoms. Increased during FM phases (191)	ED patients complaining of unexplained chest pain with anxiety and mood disorders, panic and suicidal ideation (192)
Psychogenic non-epileptic seizures. Increased at FM (95)	Anxiety & depression consultations in GP practice (122, 193)
	Panic attacks seen at psychiatric hospital (194)
	Agitation in nursing home residents (195)
Patients treated at psychiatric ER Higher admissions at FM (196)	Psychiatric ED visits between 18h00 & 06h00 (197)
Psychiatric ER visits Custer around FQ. Decreased frequency around NM and FM (165)	Psychiatric admissions and emergency presentations (198)
Psychiatric hospital admissions. Increased admissions at NM for men with psychosis (199)	Psychiatric admissions or referral to mental health services (200)
New psychiatric outpatient presentations. More patients with non-affective psychoses on FM days(201)	
Deterioration in mental state and subjective quality of life in schizophrenics during week of FM (202)	

2.1.8 Animal bites

The typically contradictory nature of lunar effect research findings is well illustrated by two consecutive articles reviewing animal bites to humans published in the December 2000 British Medical Journal. Bhattacharjee and co-authors reviewed 1 621 consecutive ED patients bitten by mammals in Bradford, England and found an increase in animal bites on and around FM compared with other three-day (and one two-day) periods in the lunar cycle (203). Thereafter, Chapman and Morrell concluded after reviewing the 1 671 dog bite patients managed by all Australian public hospital A&E departments over a one-year period that presentation for treatment was no more frequent on FM than any other time of the lunar cycle (204). Two subsequent similar studies, Frangakis and Petridou (2003) from Greece reviewing 2 642 dog bites occurring between 1 May 1996 and 21 December 1999 (205) and Bulbena and co-authors (2004) from Spain reviewing 1 203 animal bites over 4 years, found no association between bite incidents and FM or other lunar phases (194).

2.1.9 Admission to hospital

Two publications were found examining the possible association between the synodic lunar cycle, FM in particular, and hospital admissions. Neither found a significant correlation to FM. Thompson and Adams in 1996 evaluated 35 087 hospital admissions and 11 278 admissions to a monitored unit in Chicago over a four-year period (76). This retrospective analysis of hospital electronic records utilizing ANOVA methods reported that admissions on the day of FM were not

significantly different to the remaining days. The second study by Coates and co-authors from 1989 reviewed 1 444 emergency department patient trauma consultations (of which 129 patients were admitted to hospital) over a one-year period found no significant difference between FM±1 day and the remaining periods amongst the129 patients admitted to hospital (84).

2.2 Studies into an anomalistic 'lunar effect' on human behaviour and biology

Research into a possible lunar effect at lunar perigee and apogee are sparse. Pokorny (1964) found no significant relationship between apogee or perigee and homicides and suicides (164) and Lieber and Sherin (1972) (162), found no significant relationship between the frequency of homicides and the anomalistic cycle over a 15 year period, including at times of maximal lunar gravitational influence (new moon or full moon with lunar perigee). Angus (1973) found emotional disturbance greatest at apogee, the time of least lunar gravitational force in the anomalistic cycle (62). In an ED study, Danzl (1987) concluded that 'there is no correlation with chaos' in his evaluation of a single occurrence of proxigee syzygy (49). No relationship to the anomalistic lunar cycle was found studying 9 years of automobile accidents (206), paediatric mortality (123), and emergency department presentation for trauma (82). Wolbank and co-authors (2003) in analysing data from an Austrian emergency system for both the synodic and sidereal months found no influence of the moon, inclusive of perigee and apogee, on specific emergency cases (89). They, however, incorrectly defined apogee and perigee by defining apogee as perigee and vice versa. Das and co-

authors found no increase in assisted conception rates (142) unlike the small effect noted by Weigert and co-authors (207) during perigee. No correlation was found by Burke and co-authors (2011) between the anomalistic month and visual acuity in an eye with macular oedema despite finding an increase at FM (208).

2.3 Lag and confounding factors

Besides the varied definitions and examination of lunar periods and cycles findings are often expressed with apparrent bias. An often-used explanation for data demonstrating significance at a time other than expected is that the effect is 'lagged'. Sok, Mikulecky and Erzen, who appear to consider a lunar effect possible, reported an increased incidence of spontaneous pneumothorax one week before and after NM (112) or as they put it "the highest frequency of spontaneous pneumothorax in our study occurred synchronously with two days delay" (of FQ and LQ). Most accurately, this is expressed as an increase two days after FQ and LQ. Neal and College reported a small but significant increase in GP consultations six days after FM (122). This could similarly be expressed as one day before LQ. They suggested that this represented a delay in accessing consultation following patient behaviour influenced by FM. They did not, however, examine the time the bookings were actually made or the nature of the underlying conditions. Zettenig and co-authors reported increased requests for follow-up appointments three days after the FM and requests for new appointments five days afterwards (120). These periods also closely approximate FQ, viz. four and two days before FQ. Any significant interphase finding (or finding unrelated to LP) could thus be explained as a LP effect as a result of a delay, making almost any

explanation possible. Between the consideration of delayed and instant effects, the determination of any ‘lunar effect’, without markedly significant findings in keeping with the extent of belief, is difficult.

A number of factors have been (and others anticipated to be) associated with patient presentation to the ED. Calendric variables are known to influence patient ED or health care facility attendance (209-214). Seasonal changes in the incidence of disease is well documented. Weather related factors such as temperature, precipitation and hours of sunshine have also been demonstrated to play a role (213, 215, 216). For example, better weather conditions have been demonstrated to be associated with an increased incidence of trauma (81, 213) and increased parasuicide with “bad weather” (low temperatures and high precipitation) (187). Associations between meteorological factors (barometric pressure, temperature and humidity) and the timing of parturition (217, 218) have been suggested. Mortality has been related to temperature and pollution (219) with increased ED presentations of cardiac conditions related to higher environmental nitrous dioxide concentrations (220). Renal colic has been shown to be increased in hot climate (221) while onset of epistaxis to weather, season and barometric pressure (222-224). Whether it will ever be possible to control for all potentially important variables is the challenge.

2.4 Offered explanations for ‘lunar effect’

A number of possible explanations, on both endogenous and exogenous levels, have been offered for a possible lunar effect. Many depend on extrapolation from

animal studies and like the lunar effect itself little has been conclusively proven.

Some of the putative explanations for a lunar effect are listed below.

- Tidal force on body fluids (43, 49, 62, 162, 225, 226)
- The effect of lunar gravitational force (43, 49, 162, 225)
- A change in atmospheric ozone levels (225)
- Effect of lunar illumination or moonlight on activity (225, 227, 228)
- Effect of moonlight on sleep deprivation (227, 228)
- Geomagnetism (225)
- Disturbance of the Earths electromagnetic field by the Moon (225, 226)
- Weather (225)
- Ions (225)
- Extremely Low Frequency (ELF) waves (225)

Myers commented on the tidal lunar gravitational force exerted on Earth, which is a widely quoted explanation, and noted that there is no uniquely monthly component to the Earth's tides, that the tidal gravitational of New and Full Moon would be equivalent and that the gravitational effects of the twice daily high tides are greater than that of the lunar phases (226). He concluded, using the technique of *reductio ad absurdum* that if there is any 'lunacy effect' it would occur twice a day at high tides and be more pronounced at the spring tides of the New and Full Moon. Danzl added that the earth's 'tug' is 5012 times that of the Moon's 'tug'. He concluded, 'as calculated, lunar tug approximates the weight of a nongravid flea' (49). Culver, Rotton & Kelly (225), in a review article of these mechanisms, concluded that "none of these are sufficient to explain the alleged effects of the moon on human behaviour".

Physiologically, Gutman and co-authors (2011) demonstrated raised glucocorticoid levels in response to greater illumination during full moon nights with an associated diminution in foraging in a nocturnal and a diurnal rodent species. The behavioural response was suggested to be due, at least in part, to the elevated cortisol levels (229) with the exact physiological and biochemical mechanisms still to be determined (230-232). Whether cortisol levels will be shown to have an influence on human behaviour at times of greater illumination, as in rodents, will remain to be seen.

2.5 Methodology review of studies on 'lunar effect'

A wide variety of methodology has been used in studies into lunar effect, which matches the extensive variety of studies into a possible lunar effect on man. Small sample sizes, short observation periods and a wide variety of statistical techniques have been utilised. Sample size varied from the smallest, 10 events (SUDEPs) over an eight and a half year period (96) to 7 108 772 births over a 29-year period (124). The shortest period was that of a 14-week prospective study over which the menstrual cycles of 312 women were recorded (233) and the longest was the 53 years that the outcomes of 3 757 breast cancer patients were observed (234). The literature includes a number of odd studies such as a study over 25 years that reviewed 127 episodes of atrial fibrillation in a single male yielding significant results – a lesser incidence at FM (103). Studies of smaller size and shorter period tended to produce significant results while those with larger sample sizes and longer periods tended to reflect the opposite.

Statistical analyses ranged from descriptive studies, t and X^2 tests through to regression analyses and cosine curve regression analyses. Errors in statistical analysis yielding findings of a lunar influence, on a number of occasions indicated no statistically significant findings on reanalysis. Typical of this dilemma as related by May and co-authors (235) is the published increase in post-tonsillectomy haemorrhage at full moon (by Andrews in 1960) that, on reanalysis by Wunder and Schmardmüller (published in 2002), showed no statistically significant effect. Simple errors in mathematics even occur. Rotton and Kelly, who offer comprehensive analysis of 'lunar effect' research and its statistical analysis, once miscalculated Russell and Dua's studies sample size (63) in their paper in 1985 outlining the scale for BILE to be 402 rather than, the correct, 502 (64).

The varied manner in which the lunar cycle and lunar phase were addressed for the purpose of analysis renders comparison of studies and methodology difficult (see Table A16). These include *inter alia*:

- Specific LPs, most often FM and NM.
- Day of the LPs.
- Periods about LP – one, two or three days before and/or after the LP.
- A number of hours about the precise moment of a LP.
- Lunar periods – Four Quarters/phases or eight phases.
- Waxing and waning periods.
- The entire LC noting the incidences for each LD.
- LC divided into equal quarters (187).
- A number of periods of determined size (174).

Mathew and Lindesay (noted by Kollerstrom and Steffert (236)) and Sok, Mikulecky and Erzen (112) erroneously studied 28 day synodic lunar cycles.

2.6 Summary: statement of the problem

Despite much belief of a lunar influence on human behaviour and biology conclusive evidence remains elusive despite a significant body of research. Research design has been very varied including numerous methods for assessing the lunar cycle and phases and potential influence. Findings are likewise inconsistent and sometimes contradictory with much statistical and study design variation and some oddity. Culver and co-authors succinctly note, mammal and human studies have common flaws namely “small sample sizes, short periods, and a failure to replicate” (225). Failure to replicate positive findings is a significant deterrant to the acceptance of any lunar effect.

Chapter 3 MATERIALS AND METHODS

3.1 Ethics

This research was approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand – Clearance Certificate M10619 (see Appendices B and C). In addition, approval was obtained from the South African private hospital group's Research Committee and Trauma Division. The hospital group remains unnamed at their request. Documentation confirming their approval can be viewed on request. Patient and hospital anonymity was maintained. The information gathered in the database was always devoid of patient and hospital identity. Access to this data was restricted to the author, his supervisor and the statistician consulted. The data was securely held only on their computers and physical storage devices.

3.2 Study design

This research was a retrospective, descriptive, hospital-based study of all patients consulted in the South African emergency departments of a large South African private hospital group over a six-year period from 01 January 2005 to 31 December 2010. Data was gathered over a six-year period as complete data for this period was accessible and was able to be gathered in the available time. It further provided a large and adequate sample size.

3.3 Study setting and population

Data on patients consulted at each of the hospital groups emergency units in the Republic of South Africa is routinely gathered each month and entered into a central database. Patients included in this study were mainly those who had private health care cover (medical aids) or were personally able to cover the cost of their medical care. As a result, patients attending these private emergency departments were generally of a higher socioeconomic status than those attending public hospitals. All patients presenting with conditions requiring urgent intervention were assisted regardless of their financial status and were also included in this study.

Inclusion criteria:

All patients consulted in the South African emergency departments of the hospital group from the beginning of January 2005 to the end of December 2010 were included in the study.

Exclusion criteria:

No patients in any of the categories studied were excluded from the study.

3.4 Study protocol

3.4.1 Data collection

Data for the study was extracted from the large South African hospital group's South African emergency units consolidated database and was entered onto a spreadsheet for data analysis.

Source of bias:

This study included only patients seen at the South African private hospital group's emergency departments, and the findings may not be applicable to all South African emergency departments or to international units.

3.4.2 The lunar variables

Lunar variables included both synodic and anomalistic lunar variables related to the synodic or anomalistic lunar cycles. The dates of the primary phases of the lunar cycle (237), apogee and perigee (3) were obtained from the South African Astronomical Observatory's website.

Four synodic lunar variables were studied; the lunar days (LD), the days of the lunar phases (LP0), the day of lunar phase plus the day before and after (LP1), and the day of lunar phase plus two days before and after (LP2).

The lunar days studied were allocated from the 24 hour calendar day on which the New Moon fell (day 1) and subsequent days were numbered sequentially thereafter. Each of the lunar days constituted a synodic lunar period within this lunar variable. The synodic lunar cycle is 29.5306 days in mean duration and depending on the exact timing of occurrence of New Moon some lunar cycles contained 29 days and a lesser number (approximately half) 30 days (2). The day of the lunar phase (LP0) included the day on which each of the lunar phases (NM, FQ, FM and LQ) occurred. The remaining days were grouped as 'interphase'. NM, FQ, FM, LQ and the interphase constituted the synodic lunar periods within this lunar variable. Likewise, the lunar periods of the lunar variables, day of lunar

phase plus one day before and after (LP1) and two days before and after (LP2), included NM ±1 or 2 days (NM1 or NM2), FQ ±1 or 2 days FQ 1 or FQ2), FM ±1 or 2 days (FM1 or FM2), LQ ±1 or 2 days (LQ1 or LQ2) and the respective interphases. One and two days before and after the lunar synodic phase or anomalistic point were included as it was considered that if any less focused “lunar effect” existed it would be revealed over these periods that have often previously been studied.

Three anomalistic lunar variables were studied; the days of the lunar Apogee and Perigee (PA0), the day of lunar Apogee and Perigee plus one day before and after (PA1), and the day of lunar Apogee and Perigee plus the two days before and after (PA2). The remaining days with each varaible were grouped as ‘interphase’. The days of Apogee (A) and Perigee (P), the days of Apogee and Perigee plus the day before and after (A1 and P1), the day of Apogee and Perigee plus the two days before and after (A2 and P2) and the respective interphases constituted the respective anomalistic lunar periods within these lunar variables.

3.4.3 The patient consultation categories

The daily frequency of patient consultations to the emergency departments in a number of categories, some including priorities, were recorded and studied. The total number of all patients consulted in the emergency departments prioritised as P1, P2, P3 and the grand total of all patients were studied. Trauma, medical, paediatric and work injury related consultations similarly each comprised four categories, P1, P2, P3 and the total of such consultations. The single obstetric and

gynaecology, intentional self-harm, sexual assault and dog bite consultation categories comprised the total number of such consultations. The priority of these patients was not considered. The four admissions categories included the number of patient hospital admissions prioritised as P1, P2, P3 and the total number of all admissions following consultation in the emergency departments.

3.5 Data analysis

The assistance of a statistician was utilised for the analysis of the data. Outliers among the patient consultation categories (on both the high and low sides) were identified based on the univariate frequency distributions. These were checked against the hospital database and corrected where necessary. Univariate descriptive statistics and frequency distributions of all patient consultation categories were obtained. Each patient consultation category was modelled separately in terms of each of the lunar variables and controlled for calendric (year, month, day of the week and public holiday) effects. Since there were seven lunar variables, a total of seven models (four synodic and three anomalistic) were estimated for each of the 28 patient consultation categories resulting in a total 196 lunar models.

Given the nature of the data (see chapter 4), it was considered appropriate to model each patient consultation category as a function of the lunar variables by means of Poisson or negative binomial regression with a log link. Poisson regression was used when the variance was approximately equal to the mean under the model, whereas negative binomial regression was used if the Poisson

model was found to be overdispersed. In all cases, it was found that the Poisson model was overdispersed, so a negative binomial model was used (see section 4.2). Comparison of the goodness-of-fit statistics for both models for each patient consultation category-lunar variable combination analysed, showed that the negative binomial model modelled the dispersion adequately and fitted the data better than the corresponding Poisson model.

The respective interphases were used as the reference group for all lunar variables except for the lunar day where day 1 was used as the reference group. The significance of the model variables was evaluated by consideration of the Type III statistics. The 95% confidence level (p-value of <0.05) was used throughout, unless otherwise specified (see Table 4.3). Pairwise multiple comparisons (of all possible pairs) within significant independent variables were then carried out using Tukey-Kramer's multiple comparison adjustment for the *p*-values and confidence limits. Incidence ratios were obtained by exponentiating the negative binomial regression coefficients. Least-Squares (LS) means comparisons with 95% confidence intervals (CI) were calculated from the data for the models.

Calendric variables (year, month, day of the week and public holidays) were analysed to allow a comparison of the magnitude of any lunar association with calendric effects.

3.6 Software

All data gathered was entered and stored in a Microsoft Excel® (Microsoft Office 2007, Microsoft Corporation) spread sheet. Data analysis was carried out in SAS Software (238).

3.7 Methodological limitations of this study

The fidelity of the gathering and capture of data by a number of people at the South African hospital group's emergency departments determines the accuracy and quality of the database. Likewise regardless of multiple checks, data capture errors by the author may have occurred. The possibility of skewed data was, however, reduced by identifying possible incorrect outliers on the univariate frequency distributions and checking and correcting as necessary. The categories P1, P2 and P3, although determined by in-house criteria set by the hospital group based on international definitions, may involve an element of subjectivity on the part of the documenting staff member.

Chapter 4 RESULTS

4.1 Descriptive analysis

4.1.1 Lunar variables

The study included a total of 2 191 lunar days with 74 complete lunar cycles with 74 occurrences of lunar days 1 to 20 and 28 and 29, and 75 occurrences of days 21 to 27. Lunar day 30 occurred 38 times. During the study period NM, FQ and FM occurred on 74 occasions with 75 LQs and 1 894 interphase days in this model. The LQ ±1 day period occurred over 225 days with the other 3 peri-LP ±1 day periods each occurring over 222 days. There were 1 300 interphase days in this model. The LQ ±2 day period occurred over 375 days with the other 3 peri-LP ±2 day periods each occurring over 370 days and 706 interphase days.

The day of Lunar Apogee fell on 79 days and Perigee on 80 days during the study period with 2 032 interphase days. The Apogee ±1 day period occurred over 237 days with the Perigee ±1 day period occurring over 240 days and 1 714 interphase days. The Apogee ±2 day period occurred over 395 days with the Perigee ±2 day period occurring over 400 days and 1 396 interphase days in this model. Full moon and perigee coincided on 6 days as did new moon and perigee.

4.1.2 Patient consultation categories

The number of patient consultations in each category in the study are tabulated in Table 4.1. The data collection system of the hospital group was idiosyncratic with a number of separate totalled databases from which the data for this study was extracted. Not all of the categories in the various databases were utilised for this study. Some overlap occurred between some of the consultation categories in the databases so that some patients in one category formed part of another. A worker, for example, with a dog bite incurred at work featured in the work injury, dog bite, trauma and ED categories, as well as the admission categories if admitted. Despite this, each patient was tallied only once in each category and category total.

The study featured large numbers of patient consultations with a total of 3097330 Emergency Department consultations. A total of almost 1 million (962 694) trauma consultations were reviewed, 2 million (1 978 859) medical, 676 161 Paediatric, 227 965 work injuries, 45 107 Obstetrics and Gynaecology, 20 739 Intentional Self-harm, 4228 Sexual assaults, 20 597 Dog bites, and 507 029 Admissions to the hospitals from the ED's. Of the over half a million ED hospital admissions, 63% of P1 patients, 52% of P2 patients and almost 4% of P3 patients were admitted. Overall, 16% of all patients seen in the ED were admitted to hospital.

Table 4.1 Patient consultations per category

Category		Patient consultations	% of Category Total
ED	P1	91 527	3
	P2	692 000	22
	P3	2 313 803	75
	Total	3 097 330	-
Trauma	P1	27 417	3
	P2	216 446	22
	P3	718 831	75
	Total	962 694	-
Medical	P1	63 608	3
	P2	467 705	24
	P3	1 447 546	73
	Total	1 978 859	-
Paediatric	P1	5 718	1
	P2	123 630	18
	P3	546 813	81
	Total	676 161	-
Work Injuries	P1	4 099	2
	P2	40 940	18
	P3	182 926	80
	Total	227 965	-
Obstetrics & Gynaecology		45 107	-
Intentional Self Harm		20 739	-
Sexual Assaults		4 228	-
Dog Bites		20 597	-
Admissions from ED	P1	57 920	11
	P2	362 210	72
	P3	86 899	17
	Total	507 029	-

The frequency distributions and key univariate statistics of the dependent variable categories are tabulated in Table 4.2. The frequency distributions were positively skewed in most cases, which is typical of count data. The variance was larger than the mean in all cases and in many cases much larger.

Table 4.2 Daily frequency distributions and key univariate statistics per category

Category	Min	Max	Mean	Std Dev	Median	Variance/ mean
Total ED P1	12	98	42	14	39	4.5
Total ED P2	121	759	316	117	306	43.6
Total ED P3	612	2 142	1 056	196	1 014	36.5
Total ED Patients	930	2 814	1 414	240	1 358	40.9
P1 Trauma	0	39	13	5	12	2.2
P2 Trauma	29	233	99	38	95	14.6
P3 Trauma	180	683	328	55	326	9.1
Total Trauma	279	812	439	65	435	9.6
P1 Medical	7	68	29	11	27	4.0
P2 Medical	80	596	213	83	204	32.1
P3 Medical	243	1 799	661	167	612	42.1
Total Medical	436	2 343	903	215	854	51.3
P1 Paediatric	0	15	3	2	2	1.5
P2 Paediatric	5	178	56	28	52	14.4
P3 Paediatric	72	729	250	84	223	28.5
Total Paediatric	130	887	309	98	277	30.9
P1 Work Injuries	0	13	2	2	1	1.7
P2 Work Injuries	0	52	19	11	18	5.9
P3 Work Injuries	5	236	83	44	95	23.7
Total Work Injuries	8	269	104	53	119	27.0
Obstetrics & Gynaecology	4	66	21	8	20	2.9
Intentional self-harm	0	43	9	5	9	2.3
Sexual Assaults	0	13	2	2	2	1.4
Dog bites	0	32	9	5	8	2.7
P1 Admissions	6	57	26	7	26	2.0
P2 Admissions	88	287	165	33	163	6.7
P3 Admissions	12	95	40	13	38	4.2
Total Admissions	144	374	231	39	226	6.7

Graphs of the frequency distributions of each of the patient consultation categories that further illustrate the skew of the data are provided in Figures 4.1 to 4.10.

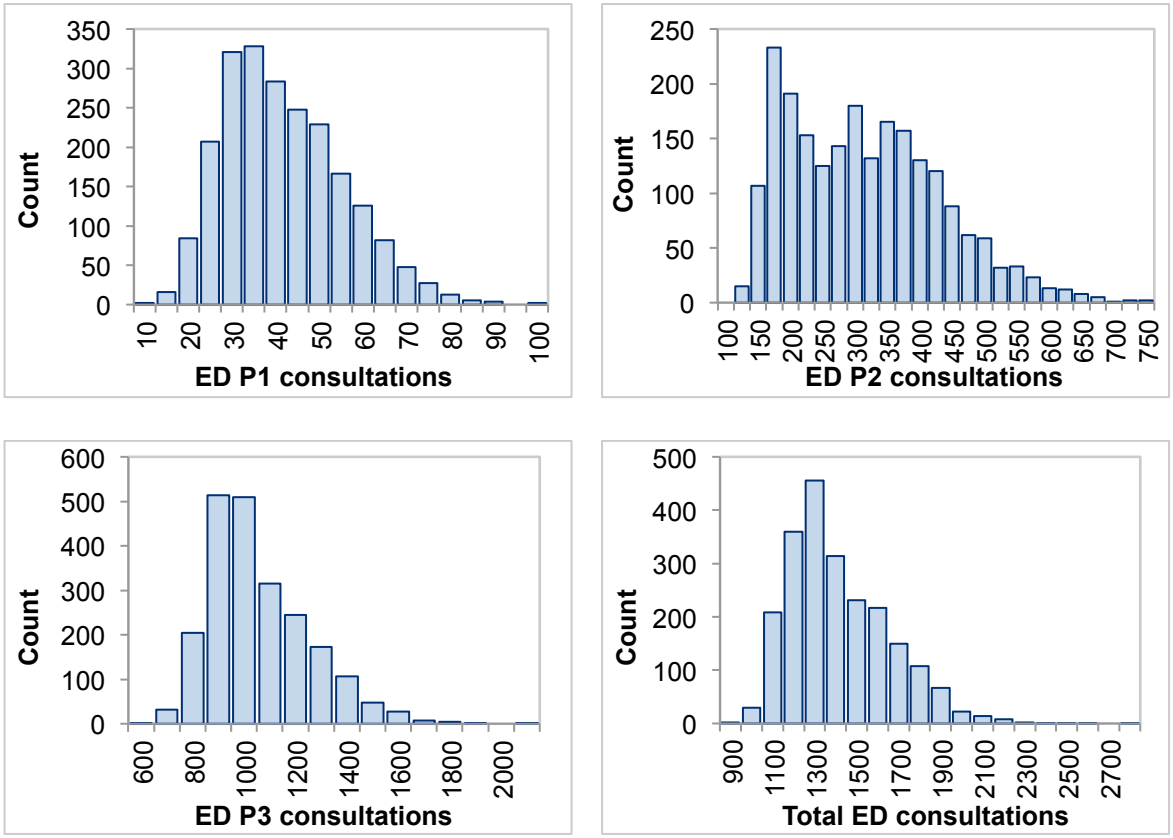

Figure 4.1 Frequency distributions of P1, P2, P3 and Total ED consultations.

All of the frequency distribution graphs for the ED consultation categories were positively skewed.

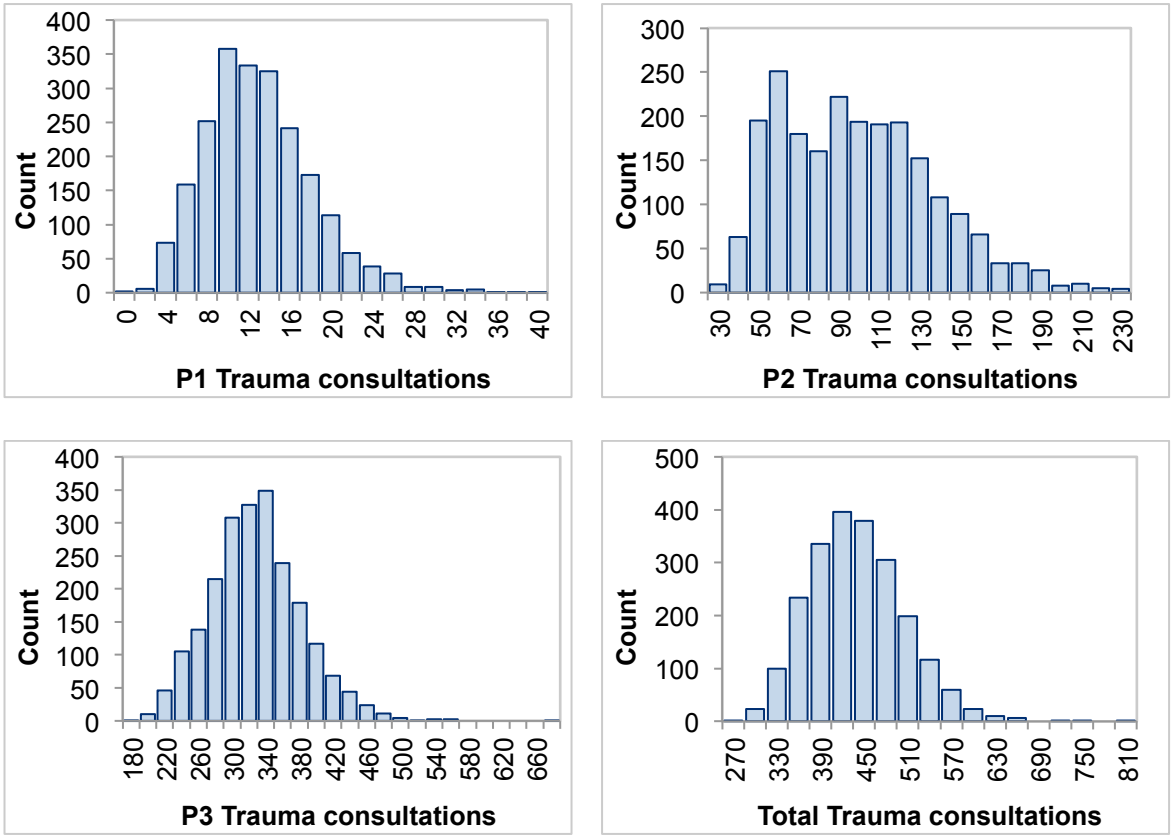

Figure 4.2 Frequency distributions of P1, P2, P3 and Total Trauma consultations.

The frequency distribution graphs for all of the trauma consultation categories were positively skewed.

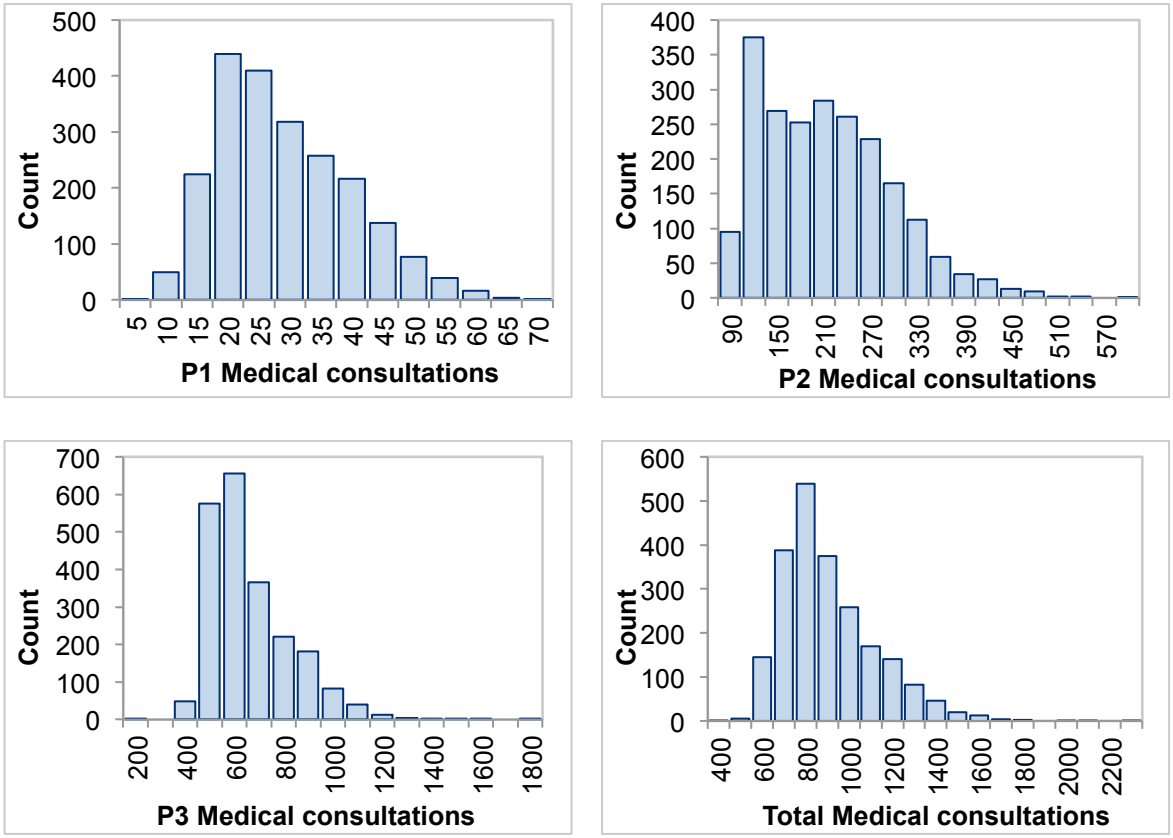

Figure 4.3 Frequency distributions of P1, P2, P3 and Total Medical consultations.

The medical categories frequency distribution graphs were all positively skewed.

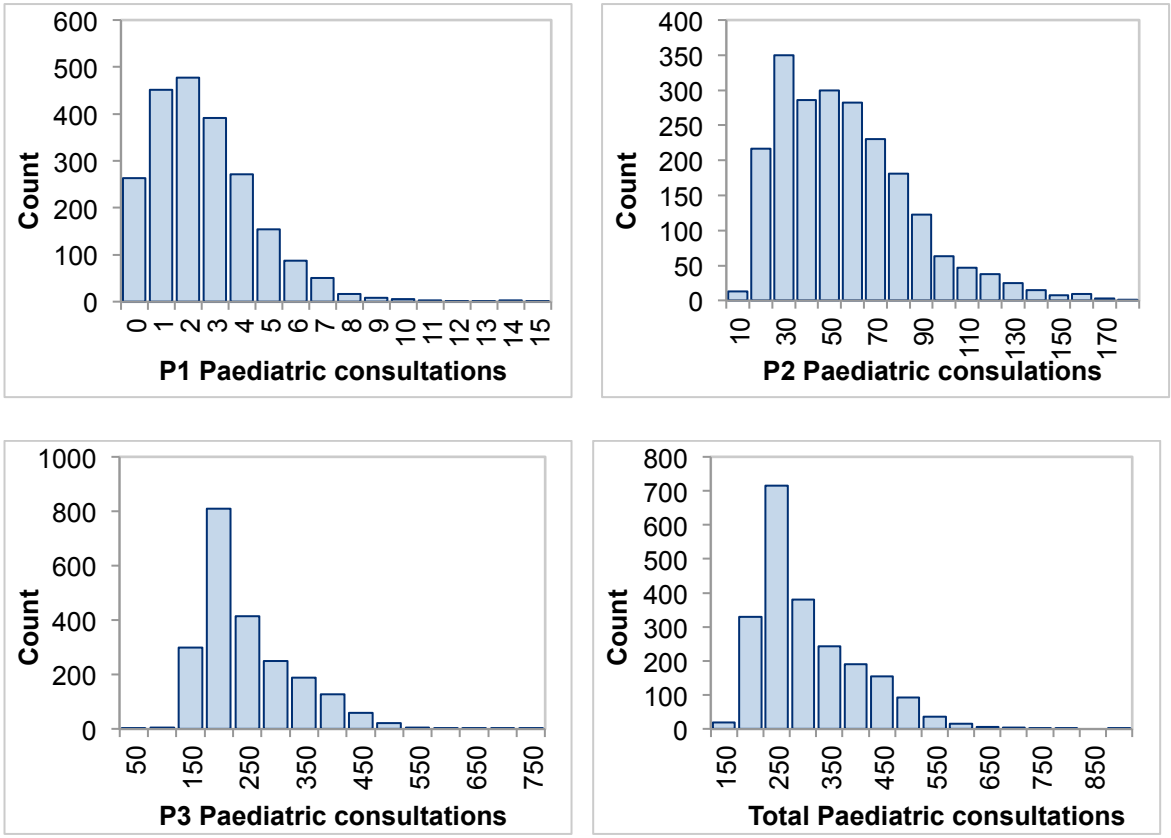

Figure 4.4 Frequency distributions of P1, P2, P3 and Total Paediatric consultations.

All of the frequency distribution graphs for the paediatric consultation categories were positively skewed.

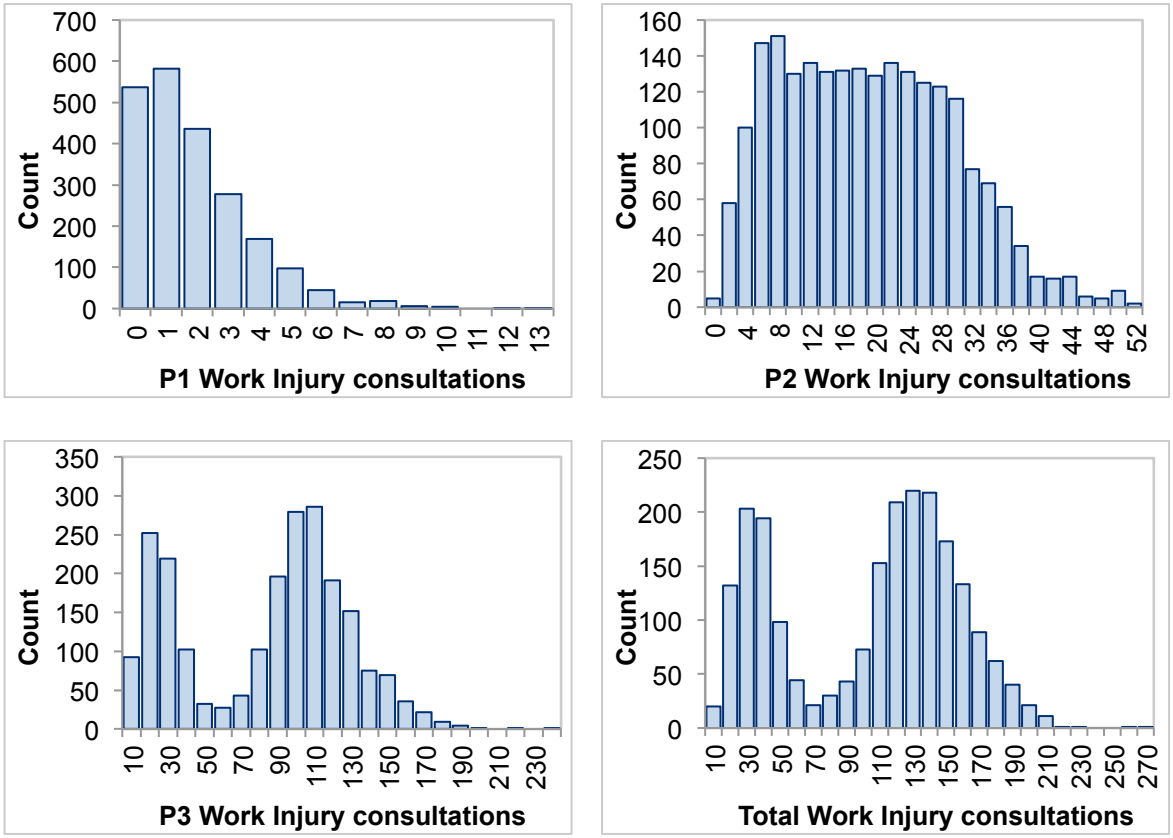

Figure 4.5 Frequency distributions of P1, P2, P3 and Total Work Injury consultations.

The frequency distribution graphs for the P1 and P2 work injury categories were positively skewed and those for the P3 and total work injury consultation categories were skewed in a bimodal distribution.

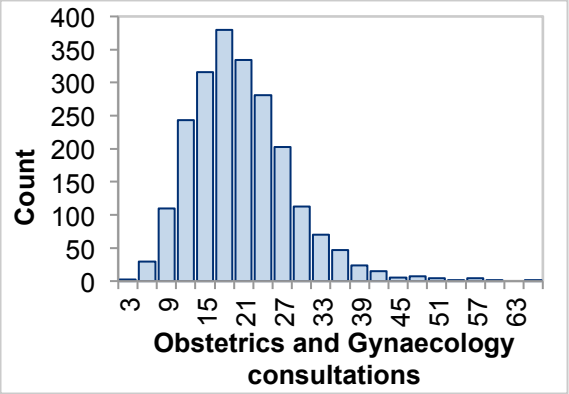

Figure 4.6 Frequency distribution of Total Obstetrics and Gynaecology consultations.

The frequency distribution graph for the total obstetrics and gynaecology consultation category was positively skewed.

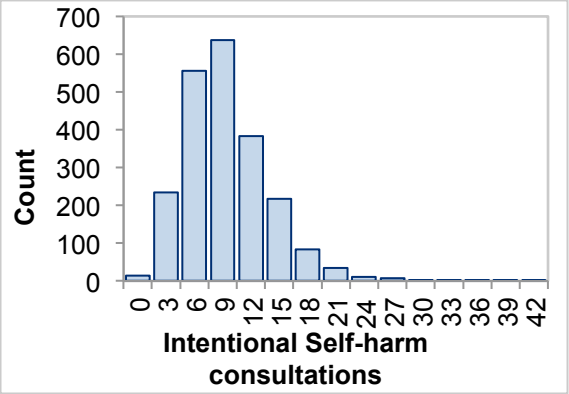

Figure 4.7 Frequency distribution of Total Intentional self-harm consultations.

The total intentional self-harm consultation category's frequency distribution graph was positively skewed.

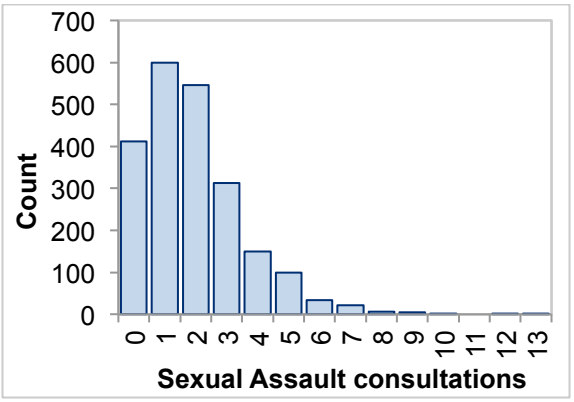

Figure 4.8 Frequency distribution of Total Sexual Assault consultations.

The frequency distribution graph for the total sexual assault consultation category was positively skewed.

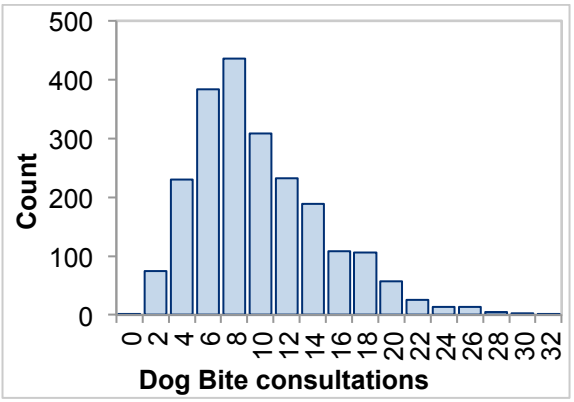

Figure 4.9 Frequency distribution of Total Dog bite consultations.

The total dog bite consultation category's frequency distribution graph was positively skewed.

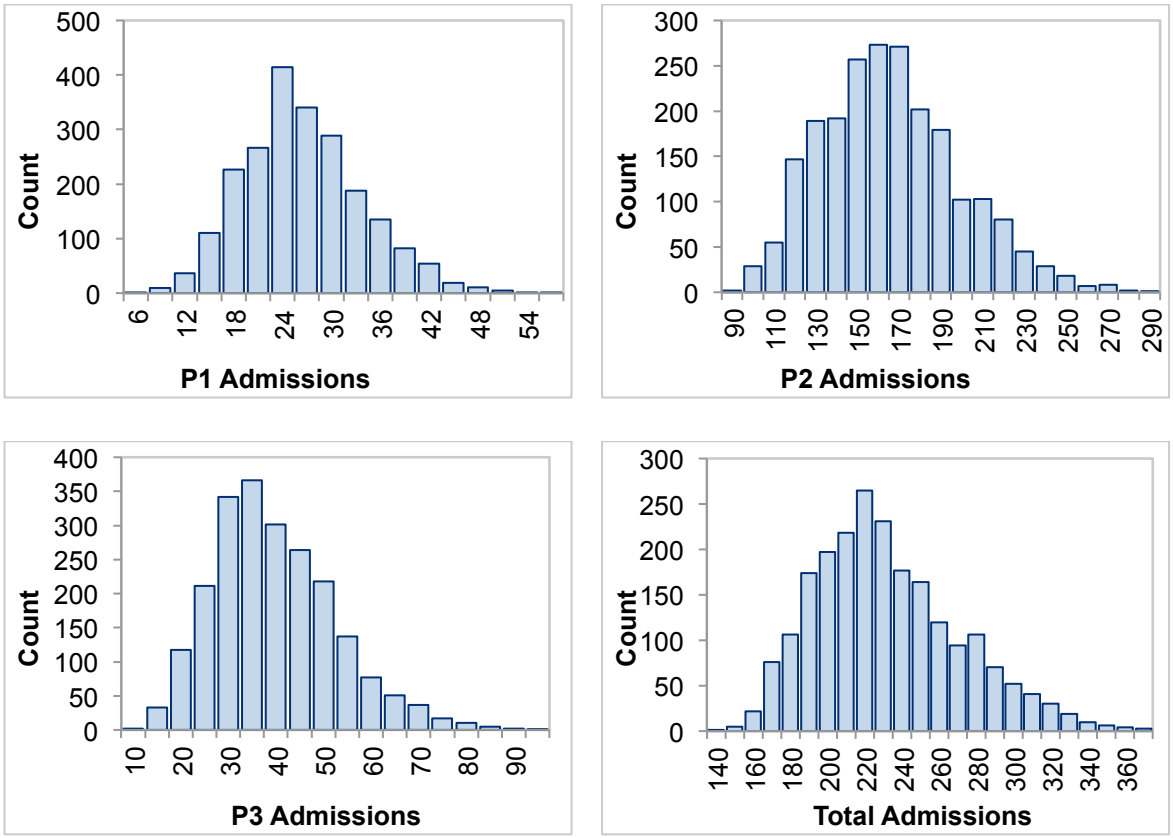

Figure 4.10 Frequency distributions of P1, P2, P3 and Total Admissions from the ED.

All of the frequency distribution graphs for the admission categories were positively skewed.

4.2 Modelling of patient counts

Each dependant variable category was modelled separately in terms of each the lunar variables and controlled for calendric (year, month, day and public holiday) effects. In total, 196 lunar models (112 synodic and 84 anomalistic) composed of the seven lunar variables, four synodic and three anomalistic, with each of the 28 categories were studied. Of these, 112 were synodic and 84 were anomalistic

lunar models. The p-values for each term in the different models (with different lunar variables) are tabulated in Table 4.3.

Table 4.3 Significance levels (p values) for the models with the categories and lunar variables

Category	Synodic lunar variables				Anomalistic lunar variables		
	Lunar day	LP 0	LP 1	LP 2	PA 0	PA 1	PA 2
P1 ED	0.66	0.43	0.49	0.48	0.74	0.53	0.26
P2 ED	0.40	0.92	0.29	0.079	0.30	0.29	0.37
P3 ED	0.94	0.49	0.19	0.16	0.72	0.70	0.67
Total ED	0.88	0.40	0.10	0.067	0.53	0.50	0.67
P1 Trauma	0.99	0.26	0.64	0.62	0.86	0.74	0.81
P2 Trauma	0.19	0.87	0.87	0.83	0.88	0.42	0.43
P3 Trauma	0.99	0.91	0.91	0.99	0.94	0.42	0.20
Total Trauma	0.97	0.96	0.90	0.98	0.96	0.20	0.14
P1 Medical	0.94	0.63	0.50	0.73	0.66	0.31	0.082
P2 Medical	0.66	0.79	0.38	**0.038**	0.33	0.056	0.19
P3 Medical	0.75	0.49	0.24	0.11	0.65	0.83	0.82
Total Medical	0.85	0.47	0.19	0.055	0.44	0.48	0.57
P1 Paediatric	0.25	0.11	0.35	0.52	0.20	0.13	0.65
P2 Paediatric	0.78	0.51	0.14	0.12	0.46	0.65	0.91
P3 Paediatric	0.79	0.16	0.055	0.10	0.22	0.37	0.52
Total Paediatric	0.78	0.18	**0.028**	**0.044**	0.20	0.32	0.52
P1 Work Injuries	0.87	0.29	0.86	0.53	0.92	0.40	0.48
P2 Work Injuries	0.32	0.36	0.67	0.70	0.89	0.61	0.52
P3 Work Injuries	0.30	0.33	0.51	0.42	0.80	0.92	0.50
Total Work Injuries	0.49	0.73	0.87	0.63	0.90	0.91	0.51
Sexual Assaults	0.39	0.54	0.15	0.70	0.90	0.24	0.51
Obstetrics & Gynaecology	0.80	0.59	0.75	0.51	0.48	0.69	0.48
Intentional self-harm	0.79	0.13	0.98	0.52	0.95	0.62	0.45
Dog Bites	0.22	0.71	0.093	0.26	0.63	0.65	0.41
P1 Admissions	**0.046**	0.49	0.55	0.38	0.67	0.53	0.60
P2 Admissions	0.78	0.97	0.42	0.12	0.061	**0.008**	0.071
P3 Admissions	0.71	0.18	0.060	0.20	**0.004**	0.055	**0.005**
Total Admissions	0.68	0.51	0.15	**0.041**	**0.007**	**0.001**	**0.005**

Significant results (p values) are highlighted in bold for convenience.

No significant results were found in 185 lunar models (107 synodic and 78 anomalistic).

Eleven models yielded significant results ($p<0.05$):

- P2 Medical consultation category with LP2
- Total Paediatric consultation category with LP1 and LP2
- P1 Admissions category with the Lunar Day (LD)
- P2 Admissions category with PA1
- P3 Admissions category with PA0 and PA2
- Total Admissions category with LP2, PA0, PA1 and PA2.

4.2.1 Significant results with the synodic lunar models

Four significant differences were found amongst the synodic lunar models (see Table 4.4) on further evaluation. A fifth, the total paediatric consultation category with LP2 revealed no significant difference on further evaluation. Table 4.5 summarises all of the significant findings found with the synodic lunar models.

Table 4.4 Summary of all significant findings with synodic lunar models

Category	Lunar Variables	Results	Incidence ratios
P2 Medical	**LP2**	**FM2 > NM2**	**1.03 (95% CI: 1.01-1.04)**
Total Paediatrics	**LP1**	**FM1 > FQ1**	**1.04 (95% CI: 1.01-1.07)**
		FM1 > I	**1.03 (95% CI: 1.01-1.05)**
	LP2	FM2 > NM2	No significant difference on further evaluation
P1 Admissions	**Lunar Days**	**Day 11 > Day 5**	**1.15 (95% CI: 1.08-1.24)**
Total Admissions	**LP2**	**FM2 > NM2**	**1.02 (95% CI: 1.01-1.03)**

4.2.1.1 Model of the Medical P2 consultation category with the synodic lunar variable of LP2

The synodic lunar variable of LP ±2 days for the category of P2 medical consultations was found to be statistically significant on patient counts (p=0.038). None of the other medical categories were significantly different for any of the lunar variables (synodic or anomalistic) (See Table 4.3). Further analysis revealed that the PPCs for this category at FM ±2 days were significantly higher than those at NM ±2 days. The incidence ratio at FM ±2 days compared to NM ±2 days was 1.03 (95% CI: 1.01-1.04). None of the other lunar variables or phases were found to be significantly different with this category.

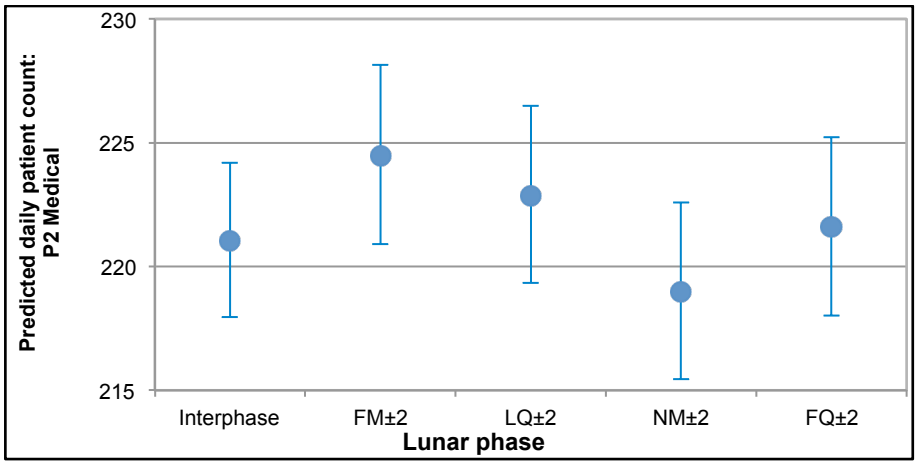

Figure 4.11 PPC for P2 Medical vs LP2.
(LS-means and their 95% confidence intervals).

This lunar association represents a small but significant increase of 3% more P2 medical consultations at FM ±2 days compared to the NM ±2 days, controlling for all the other variables in the model.

4.2.1.2 Models of the Total Paediatric consultation category with the synodic lunar variables of LP1 and LP2

The models of LP ±1 day and LP ±2 days with the total paediatric consultations category were found to be significant on patient counts (p=0.028 and p=0.044 respectively). None of the other paediatric categories were significantly different for any of the lunar variables (See Table 4.3). The predicted patient counts of FM ±1 day for the category of total paediatric consultations were significantly higher than those at the Interphase and FQ ±1 day. The incidence ratio at FM ±1 day compared to the Interphase was 1.03 (95% CI: 1.01-1.05) and at FM ±1 day compared to FQ ±1 day was 1.04 (95% CI: 1.01-1.07) (see Table 4.4).

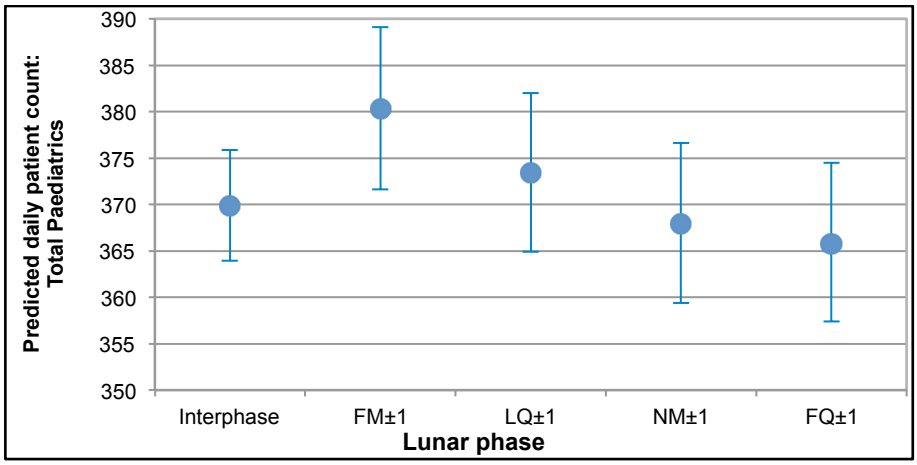

Figure 4.12 PPC for Total paediatric vs LP1.
(LS-means and their 95% confidence intervals).

The significant lunar association for the category of total paediatric consultations again represents a small but significant increase of 3% and 4% more patients at FM ±1 day compared to the interphase and FQ ±2 day respectively, controlling for all the other variables in the model.

Pairwise comparisons, after adjusting the significance level to allow for multiple significance testing, did not show any significant differences between the groups of LP ±2 days. The effect of this lunar variable was thus disregarded.[c]

4.2.1.3 Model of the P1 Admissions category with the synodic lunar variable of days of the lunar cycle

This model of lunar days with the category of P1 admissions was statistically significant on patient counts (p=0.046). None of the other models were found to be significantly different with this category (See Table 4.3). The PPCs on day 11 were significantly higher than those on day 5 (See Table 4.4). The incidence ratio on day 11 compared to day 5 was 1.15 (95% CI: 1.08-1.24), i.e. 15% more patients were expected on day 11 compared to day 5. No other statistically different PPCs were observed with this model (see Table 4.4).

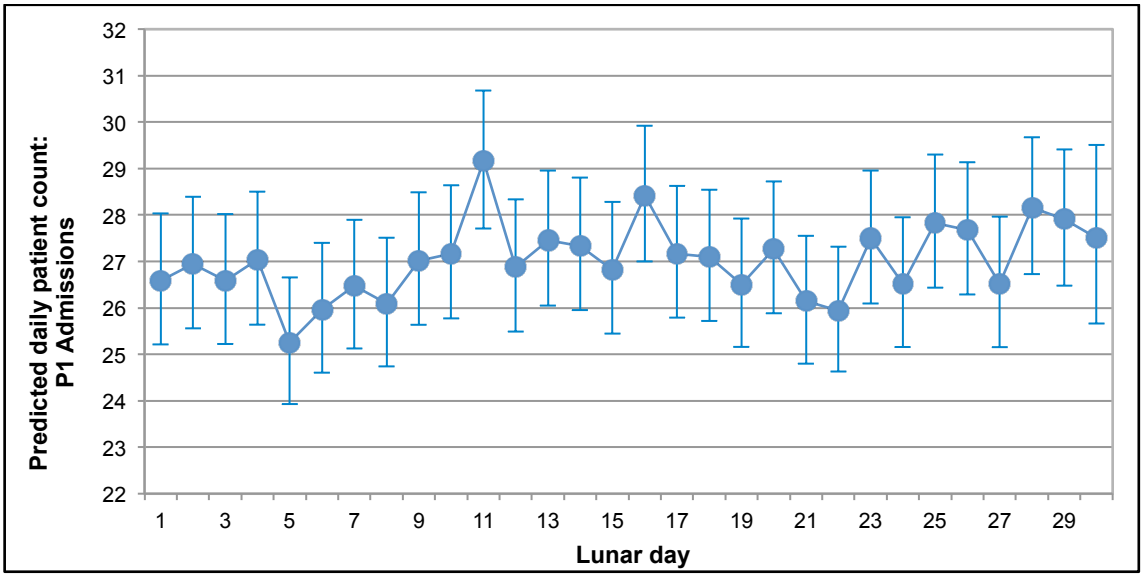

Figure 4.13 PPC for P1 Admissions vs days of the synodic lunar cycle.
(LS-means and their 95% confidence intervals).

[c] This can occur when marginal significance of an effect (p near 0.05) is found and the groups are unbalanced.

The significant lunar association demonstrated above represents a 15% swing in P1 patient admissions from the busiest day (day 11) of the lunar cycle to the quietest (day 5).

4.2.1.4 Model of the Total Admissions category with the synodic lunar variable of LP2

The patient counts for the category of total admissions modelled with the lunar variable of LP ±2 days (p=0.041), the day of perigee and apogee (p=0.007), perigee and apogee ±1 day (p=0.001) and perigee and apogee ±2 days (p=0.005), were found to be statistically significant (see Table 4.3). The PPCs at FM ±2 days were significantly higher than those at NM ±2 days. The incidence ratio at FM ±2 days compared to NM ±2 days was 1.02 (95% CI: 1.01-1.03) (see Table 4.4).

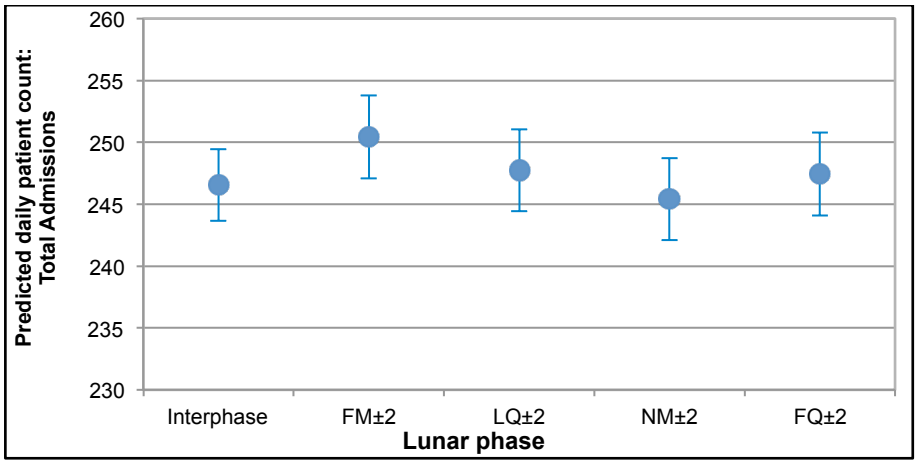

Figure 4.14 PPC for Total Admissions vs LP2.
(LS-means and their 95% confidence intervals).

This represents a small but significant 2 % increase in total admissions at FM ±2 days compared to NM ±2 days.

4.2.2 Significant results with anomalistic lunar models

Six significant differences were found amongst the anomalistic lunar models (see Table 4.3). Table 4.5 summarises all of the significant findings found with the anomalistic lunar models.

Table 4.5 Summary of all significant findings with anomalistic lunar models.

Category	Lunar variables	Results	Incidence ratios
P2 Admissions	PA1	A1 > P1	1.03 (95% CI: 1.01-1.05)
		I > P1	1.02 (95% CI: 1.01-1.04)
P3 Admissions	PA0	A > P	1.12 (95% CI: 1.05-1.19)
		A > I	1.06 (95% CI: 1.01-1.11)
	PA2	A2 > P2	1.04 (95% CI: 1.01-1.08)
		I > P2	1.04 (95% CI: 1.01-1.06)
Total Admissions	PA0	A > P	1.05 (95% CI: 1.02-1.08)
		I > P	1.03 (95% CI: 1.01-1.05)
	PA1	A1 > P1	1.03 (95% CI: 1.01-1.04)
		I > P1	1.02 (95% CI: 1.01-1.04)
	PA2	A2 > P2	1.02 (95% CI: 1.01-1.03)
		I > P2	1.02 (95% CI: 1.00-1.03)

4.2.2.1 Model of the P2 Admissions category with the anomalistic lunar variable of PA1

The model of perigee and apogee ±1 day (PA 1) for the category of P2 admissions was significant on patient counts (p=0.008) (See Table 4.3). The PPCs at apogee ±1 day and the interphase were significantly higher than those at perigee ±1day. The incidence ratio at apogee ±1 day compared to perigee ±1 day was 1.03 (95% CI: 1.01-1.05) and that of the interphase compared to perigee ±1 day was 1.02 (95% CI: 1.01-1.04) (see Table 4.5).

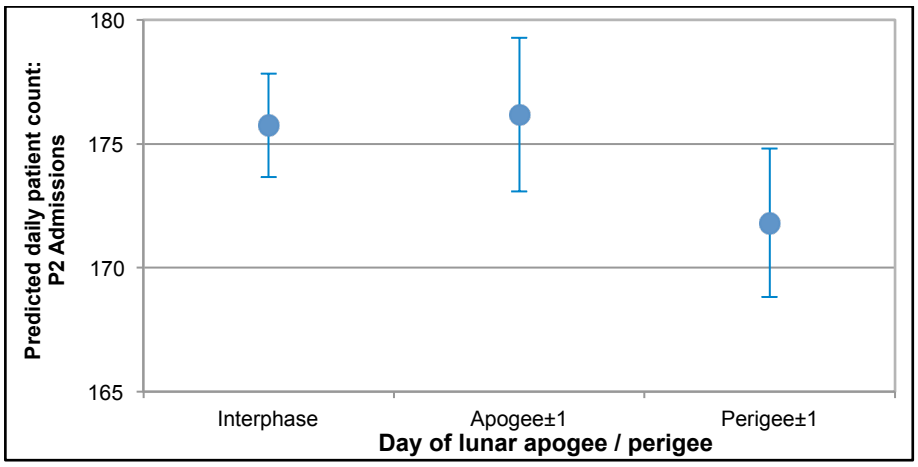

Figure 4.15 PPC for P2 Admissions vs anomalistic month – PA1.
(LS-means and their 95% confidence intervals).

This represents significant 2 and 3% decreases in P2 admissions at perigee ±1 day compared to interphase and apogee ±1 day respectively.

4.2.2.2 Models of the P3 Admissions category with the anomalistic lunar variables of PA0 and PA2

The models of the day of perigee and apogee (PA 0) and perigee and apogee ±2 days (PA 2) were significant on patient counts (p=0.004 and p=0.005 respectively) (See Table 4.3). The PPCs on the day of apogee were significantly higher than those on the day of perigee and the interphase (See Figure 4.16). The incidence ratio at apogee compared to perigee was 1.12 (95% CI: 1.05-1.19) and that of the day of apogee compared to the interphase was 1.06 (95% CI: 1.01-1.11). This reflects an increase in P3 admissions of 6 and 12% at apogee compared with the interphase and perigee respectively (see Table 4.5).

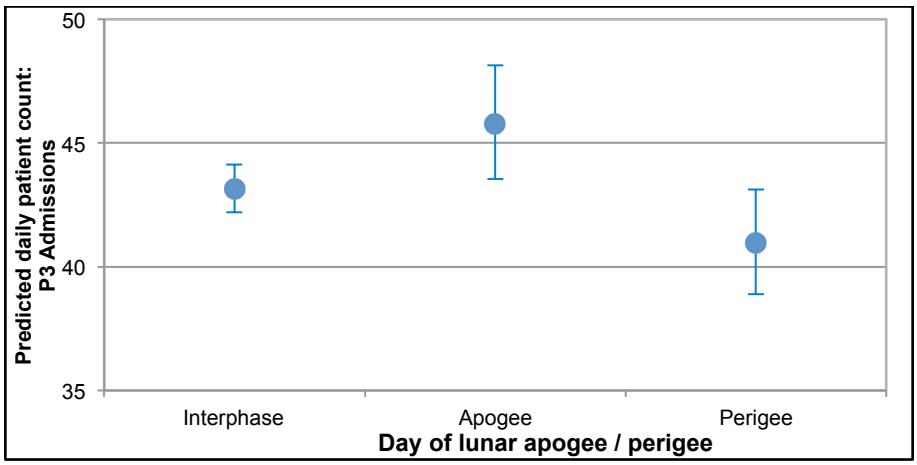

Figure 4.16 PPC for P3 Admissions vs anomalistic month – PA0.
(LS-means and their 95% confidence intervals).

The PPCs at apogee ±2 days and the interphase were significantly higher than those at perigee ±2 days (See Figure 4.17). The incidence ratio at apogee ±2 days compared to perigee ±2 days was 1.04 (95% CI: 1.01-1.08) and that of the interphase compared to perigee ±2 days was 1.04 (95% CI: 1.01-1.06) indicating a 4% decrease in P3 admissions at perigee ±2 days compared to both apogee ±2 days and the interphase (see Table 4.5).

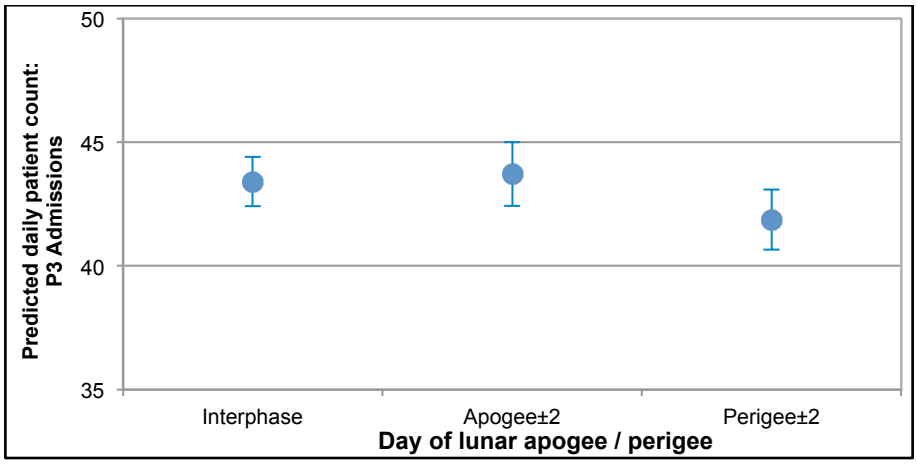

Figure 4.17 PPC for P3 Admissions vs anomalistic month – PA2.
(LS-means and their 95% confidence intervals).

4.2.2.3 Models of the Total Admissions category with the anomalistic lunar variables of PA0, PA1 and PA2

The models of the day of lunar perigee and apogee (PA0), perigee and apogee ±1 day (PA1) and perigee and apogee ±2 days (PA2) for the category of total admissions categories were significant on patient counts (p=0.007, p=0.001 and p=0.005 respectively) (See Table 4.3). The PPCs on the day of apogee and the interphase were significantly higher than those on the day of perigee (See Figure 4.18). The incidence ratio at apogee compared to perigee was 1.05 (95% CI: 1.02-1.08). Similarly, the incidence ratio at the interphase compared to perigee was 1.03 (95% CI: 1.01-1.05). This reflects a 3 and 5% decrease in total admissions at perigee compared to interphase and at apogee respectively (see Table 4.5).

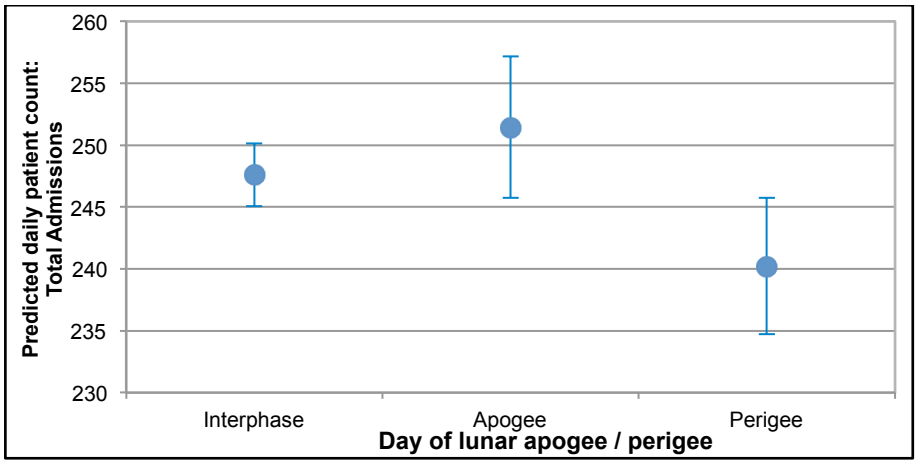

Figure 4.18 PPC for Total Admissions vs anomalistic month – PA0.
(LS-means and their 95% confidence intervals).

The PPCs for total admissions at apogee ±1 day and the interphase were significantly higher than those at perigee ±1 day (see Figure 4.19). The incidence ratio at apogee ±1 day compared to perigee ±1 day was 1.03 (95% CI: 1.01-1.04)

and that of the interphase compared to perigee ±1 day was 1.02 (95% CI: 1.01-1.04) reflecting a 2 and 3% decrease in total admissions at perigee compared with the interphase and apogee (see Table 4.6).

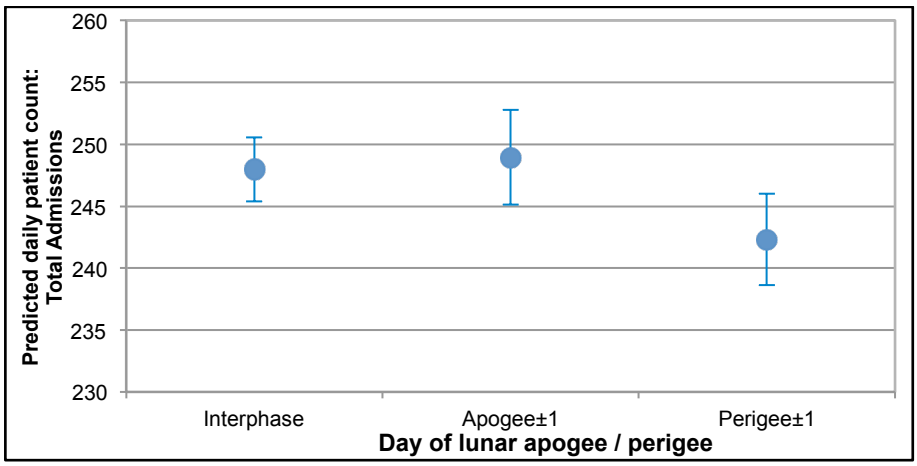

Figure 4.19 PPC for Total Admissions vs anomalistic month – PA1.
(LS-means and their 95% confidence intervals).

The PPCs at apogee ±2 days and the interphase were significantly higher than those at perigee ±2 days (See Figure 4.20). The incidence ratio at apogee ±2 days compared to perigee ±2 days was 1.02 (95% CI: 1,01-1,03). Similarly, the incidence ratio at the interphase compared to perigee ±2 days was 1.02 (95% CI: 1.00-1.03). This represents a 2% decrease in total admissions with this lunar variable at perigee compared with both the interphase and apogee (see Table 4.5).

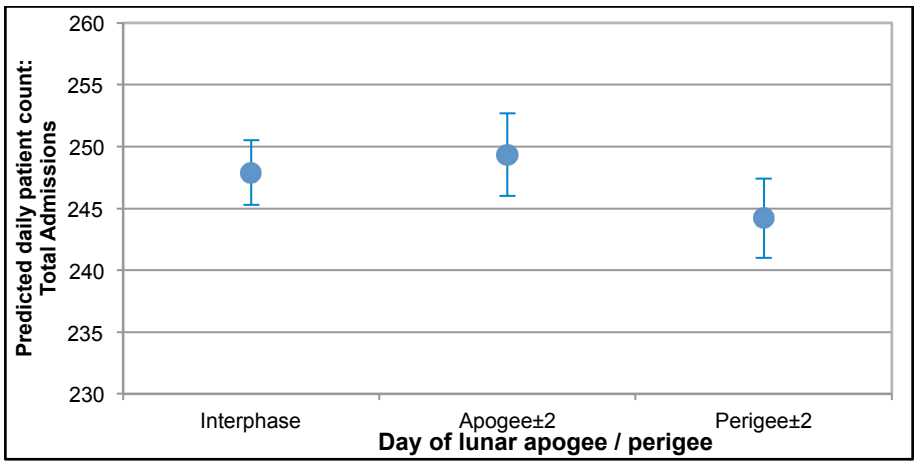

Figure 4.20 PPC for Total Admissions vs anomalistic month – PA2.
(LS-means and their 95% confidence intervals).

4.2.3 Significant lunar results in perspective with calendric results

The demonstrated significant synodic and anomalistic lunar results incidence ratios outlined in the previous sections are smaller than those of the calendric variables and in some instances much smaller. By way of illustration, patient numbers on a Sunday (compared with a Monday) for both the synodic and anomalistic models demonstrating significance increase from 18 to 60% and 19 to 27% respectively. Patient numbers on a public holiday (compared with non public holidays) for the synodic and anomalistic models demonstrating significance rise from 8 to 60% and 17 to 28% respectvely (Tables 4.6 and 4.7).

Table 4.6 Incidence ratios of calendric variables for significant synodic lunar models

	Models			
Category	**P2 Medical**	**Total Paediatric**	**P1 Admission**	**Total Admission**
Lunar variables	**LP2**	**LP1**	**Lunar days**	**LP2**
Day (compared to Monday) – Incidence ratios				
Sunday	**1,24 (1,22-1,26)**	**1,60 (1,56-1,63)**	**1,18 (1,14-1,22)**	**1,20 1,18-1,22)**
Public holiday (compared to non public holiday) – Incidence ratios				
Public holiday	**1,26 (1,23-1,29)**	**1,60 (1,55-1,65)**	**1,08 (1,04-1,14)**	**1,18 (1,15-1,20)**

Table 4.7 Incident ratios of calendric variables for significant anomalistic lunar models

	Models			
Category	**P2 Medical**	**Total Paediatric**	**P1 Admission**	**Total Admission**
Lunar variables	**LP2**	**LP1**	**Lunar days**	**LP2**
Day (compared to Monday) – Incidence ratios				
Sunday	**1,24 (1,22-1,26)**	**1,60 (1,56-1,63)**	**1,18 (1,14-1,22)**	**1,20 1,18-1,22)**
Public holiday (compared to non public holiday) – Incidence ratios				
Public holiday	**1,26 (1,23-1,29)**	**1,60 (1,55-1,65)**	**1,08 (1,04-1,14)**	**1,18 (1,15-1,20)**

The numerical impact of significant increased calendric incidence ratios is marked compared with significant lunar increases. Numerical increases demonstrated in table 4.8 were calculated from PPC's that were LS (Least-Squares) Means (i.e. from daily patient counts estimated over balanced values of the other variables in the model). Increased total paediatric patients, for the lunar variable LP1, would represent 14 and ten additional consultations nationally over the lunar variable period FM1 compared with FQ1 and the interphase respectively. Total admissions

for the lunar variable PA0 would represent 11 and eight additional consultations nationally on the day of apogee and during the interphase compared with the day of perigee respectively. By comparison, increased total ED consultations for the lunar variable of lunar day comparing Sunday with Thursday would represent 562 additional consultations nationally on a Sunday and 406 additional consultations nationally on a public holiday compared with a non-public holiday.

Table 4.8 Estimated increased total numbers of patients consulted or admitted daily for all EDs with selected models

Category	Lunar variable	Comparison	Increased Patients
P2 Medical	LP2	FM2 > NM2	5
Total Paediatrics	LP1	FM1 > FQ1	14
Total Paediatrics	LP1	FM1 > I	10
P1 Admissions	Lunar day	Day 11 > Day 5	4
Total Admissions	LP2	FM2 > NM2	5
P1 Admissions	Lunar day	Sunday > Wednesday	8
P2 Admissions	PA1	A1 > P1	4
P2 Admissions	PA1	I > P1	4
P3 Admissions	PA0	A > P	5
P3 Admissions	PA0	A > I	2
P3 Admissions	PA2	A2 > P2	2
P3 Admissions	PA2	I > P2	1
Total Admissions	PA0	A > P	11
Total Admissions	PA0	I > P	8
Total Admissions	PA1	A1 > P1	7
Total Admissions	PA1	I > P1	6
Total Admissions	PA2	A2 > P2	5
Total Admissions	PA2	I > P2	4
Total ED	Lunar day	Saturday > Monday	80
Total ED	Lunar day	Sunday > Monday	312
Total ED	Lunar day	Saturday > Thursday	330
Total ED	Lunar day	Sunday > Thursday	562
Total Admissions	Lunar day	Saturday > Monday	18
Total Admissions	Lunar day	Sunday > Monday	51
Total Admissions	Lunar day	Saturday > Thursday	50
Total Admissions	Lunar day	Sunday > Thursday	83
Total Paediatrics	Lunar day	Saturday > Monday	107
Total Paediatrics	Lunar day	Sunday > Monday	213
Total Paediatrics	Lunar day	Saturday > Thursday	153
Total Paediatrics	Lunar day	Sunday > Thursday	259
Total ED	Lunar day	Public holiday > non Public Holiday	406
Total Admissions	Lunar day	Public holiday > non Public Holiday	40
Total Paediatrics	Lunar day	Public holiday > non Public Holiday	175

Chapter 5 DISCUSSION

5.1 General comments

This research, which modelled a number of emergency department consultation and admission categories with a number of synodic and anomalistic lunar variables in order to detect any lunar associations, yielded a small number of significant results. It, however, produced an even larger number of non-significant findings.

Sample sizes and the period of this study were larger than prior studies and, in many instances, much larger. For example, two studies yielding no significant results, Zargar and co-authors studied 54 457 ED trauma patients seen over 13 months in Iran (82) and Nunez and co-authors 1 100 victims of aggression treated at a Canary Island ED over one year (167). Stomp and co-authors studied 354 150 ED trauma patient visits over 36 years in the Groningen region of the Netherlands and demonstrated a lower incidence at FM than NM (81). This study evaluated a total of 962 694 trauma patient consultations at a South African private hospital group's EDs over six years and found no significant lunar association. Furthermore, this study, evaluated of a total of over 3 million ED consultations and like previous studies with smaller numbers found no evidence of a lunar effect on total ED patient volumes and presentations. Some differences in patterns of patient presentation and admission were noted in other categories.

5.2 Non-significant results

The vast majority of lunar models (186 out of 196) both synodic (108 out of 112) and anomalistic (78 out of 84) revealed no significant change in patient consultation volumes related to both the synodic and anomalistic lunar variables. None of the lunar variable models with the ED, trauma, work injury, O & G, intentional self-harm, sexual assault and dog bite consultation categories were significant. Models with the P1, P3 and total medical consultations and P1, P2 and P3 paediatric consultations were not significant either. These confirm that there is no lunar correlation in these models and represent a failure to replicate results as is often the case in “lunar effect” research.

P1, P2, P3 and Total ED patient consultation volumes showed no significant differences for any of the lunar variables. This is confirms the findings of the two prior ED studies (76, 77) that there is no lunar correlation with the volumes or the priority of patients presenting to the ED.

The number of ED trauma patient consultations, as with general ED consultation volumes, were not significant for any of the lunar variables. This, again, is in keeping with most of the studies reviewed. Although not identical populations, this study’s trauma consultations do not support findings in prior publications that reported significant but inconsistent differences at and around NM and FM for trauma post-motor vehicle accident (59, 80, 81). Sitar demonstrated increases two and three days after NM and around FM (80), Nijsten and Willensen fewer around

FM (59) and Templer and co-authors increases at NM and FM that were no longer demonstrated on later reevaluation and control for calendric variables (78).

No significant findings regarding work injuries were demonstrated, which is in keeping with prior studies found in this regard.

Considering the volume of research into a possible lunar effect on female biology, predominantly into labour, delivery and the menstrual cycle this study did not demonstrate any significant difference between any of the lunar models with obstetric and gynaecology consultations in the ED. Explanation for (or confounding of this) this may be that many O&G patients bypass the ED and present directly to their specialist or that the combination of obstetrics and gynaecology patients results in the positive effect of one cancelling the negative effect of the other, resulting in no significant effect being observed.

Despite the body of research on crime, sexual assault, aberrant behaviour, intentional self harm and the human psyche, no significant differences were noted between any of the lunar models with consultations following sexual assault or intentional self harm.

As noted by three of the four studies reviewed, no significant differences were found in any of the the lunar models with the category of human consultations following dog bites. It appears that neither the animal (dog) nor the human are under an effect of the moon in these animal-human interactions.

Of the medical consultations categories in this study, all of the lunar models but that with LP ±2 days and the P2 medical consultations category were not significant.

The majority of the paediatric consultation categories also showed no significant differences for the lunar variables with one exception, that of LP ±1 day and the total paediatric consultation category.

Of the admissions categories, where a number of significant results were found, 20 of the 28 models demonstrated no significant results.

5.3 Significant results

Despite the history and extent of popular belief in a lunar effect few significant results were noted. A total of only ten significant differences, four synodic and six anomalistic were demonstrated out of 196 lunar models. The admissions categories demonstrated the largest number of significant results mainly related to the anomalistic cycle. Eight of these models, two synodic and six anomalistic, revealed significant results.

In three significant associations identified between synodic lunar variables and a category (P2 medical, total paediatric and total admissions), the lunar variable periods including and about FM were noted to have significantly higher daily patient counts than some of their comparisons within the model. All of the FM lunar variable periods (FM, FM1 and FM2), however, were not significantly

different to all of the comparible lunar variable periods or to consistent lunar variable periods. The effect was small with between 2% to 4% more patients consulted around FM than at the comparable lunar variable periods or interphase. Few of the similar lunar models approached significance.

Previously, varied specific ‘medical’ studies have reported significant changes around different lunar phases with much failure to replicate. Only one category was found to reach significance in this study. The model of P2 medical consultations with the synodic lunar variable of LP2 reached significance demonstrating a 3% increase in consulations around FM2 compared with NM2. Daily consultation patient counts around FM2 were not consistently increased over all of the compared lunar variable periods. No significant differences were noted in the similar but shorter, focused synodic lunar variables of LP0 and LP1. In the light of this, the relevance of this finding is doubtful and could be attributed to a type I error.

The model of L2 and the total paediatric consultations category was found to be significant after controlling for the calendric variables. Pairwise comparisons, however, did not show significance and therefore this observation was disregarded. This possibly indicates that the effect is more concentrated around FM1 rather than FM2.

The model of LP1 and the total paediatric category showed significant increases between FM1 and the interphase and FQ1 with respectively 3% and 4% more patients consulted. No significant differences were shown between the FM and the

NM and LQ periods. The effect, however, was not concentrated on the day of FM as the LP0 model was not significant.

The P3 paediatrics category, that contitutes the majority of patients in the total paediatric category (81%), approached significance for the LP1 variable (p=0.055). The model with FM1 and total paediatric consultations was not significantly different to all of the lunar periods and none of the other models with this category were significantly different.

The model with the total admissions category and the lunar variable LP2 was significant with 2% more patients consulted at FM ±2 days compared with NM2. Again, the other lunar synodic periods in this lunar variable were not significantly different from the FM period and the focused synodic lunar variables of LP1 and LP0 demonstrated no significant differences in their models with the total admissions category.

The lunar variable periods with FM always demonstrated the significant increases but for all the belief in a synodic lunar effect, the demonstrated FM associations were not significantly different from all of the comparable lunar variable periods and not reproduced in the similar models. This may indicate that these small but significant associations were due to a confounding factor for which the study does not account or that these are not reproducable and are chance findings despite the size and length of the time period of this study.

Evaluation of models with synodic lunar cycle days and the categories demonstrated a single significant finding. PPCs were significantly higher on day 11

than day 5 for the P1 admissions category with 15% more patients consulted. None of the other admission categories for this lunar variable demonstrated significant differences. All of the other synodic lunar variables similarly showed no difference to this or any of the admission categories except for an increase in total admissions over FM2. Days 5 and 11 are between NM and FM in the period of the waxing moon on either of FQ and would form part of the interphase, which has not demonstrated any other significant findings. Thompson and Adams (76) in a similar study found no significant correlation with lunar cycle day comparisons of hospital and monitored unit admissions from the ED. Their highest and lowest non significant results are, however, discordant with these results. This observation is most likely spurious or as a result of unidentified confounding factor.

All of the significant findings with the anomalistic lunar models occured with the admissions categories. The admission categories showed a number of significant differences with the anomalistic lunar models. None of the other categories demonstrated any significance with the anomalistic lunar models. Previous research reported few associations with the anomalistic cycle. No prior research was found suggesting that apogee or perigee was associated with significant differences in the frequency of admissions from the ED.

The higher priority admission category of P1 admissions, that included the more acute and severe conditions, revealed no significant differences (or any that approached significance) with the anomalistic models. The lower priority and less acute admission categories of P2 and P3 admissions demonstrated three significant differences for the anomalistic lunar models and all of the rest

approached significance. The P2 and P3 admissions categories contributed 89% of total admissions. All of the total admissions categories anomalistic models were significant. These significant findings all demonstrated consistently fewer admissions at and around perigee with between 2% to 12% less patients admitted than during the interphase (except the P3 Admissions-day of perigee and apogee model) and at and around apogee.

None of the patient consultation categories were significant with any of the anomalistic lunar variables, suggesting that this association is related to causes specific to admissions from the ED to the hospital. Factors which could be responsible for fewer admissions at and around perigee would involve either the patient or the doctor. Likely options would include decreased admissions by ED physicians, increased patient refusals of admission at perigee or that less ill patients presented at perigee. These would all require furher research to identify.

Finally, significant calendric increases place a larger burden on EDs than the smaller significant lunar results. Assuming the South African private hospital group has ‘tens’ of emergency units nationally then the significant lunar models would contribute less than one extra patient per unit per day. Calendric variables increasing patient presentation patterns, however, would contribute as many as ten or more extra patients per unit per day.

5.4 Limitations of this research

Although the effect of the calendric variables of year, month, day of the week and public holiday were considered and controlled, the effect of the month-end and season were not. Broad ED consultation and admission categories based on patient presentation priority were studied. More specific conditions presenting to the ED that may have lunar associations were not considered and therefore could not be identified. National results of the private hospital group's EDs were utilised and as a result specific local or regional effects likely to impact upon ED attendance and consultation were not considered. For example, consideration of local weather related variables such as temperature, humidity, barometric pressure and precipitation were not possible. The influence of a vast range of further possible confounding variables such as socio-political disruptions (including industrial action, transport disruptions and civil disturbances), lunar illumination (including lunar position and duration of presentation), solar effects and geomagnetic changes were not considered or controlled.

5.5 Strengths of this research

This research was the first known such attempt to identify lunar associations with presentation for consultation or admission to South African EDs. It utilised larger sample sizes (in many cases, much larger) and a longer study period than most prior research. A wide array of categories of patient presentation to the ED and admission to the hospital from ED were examined attempting to identify possible lunar associations with both the synodic and anomalistic lunar cycles. Data was

controlled for most calendric variables, which might otherwise have impacted upon the findings.

Patients presenting to the EDs studied in this research received prompt attention and gratification of their need for medical attention. Any lag or delay in presenting as a result of any behaviour induced by a lunar effect is therefore unlikely in this research.

Chapter 6 CONCLUSIONS

Unlike many of the mammal and human studies that Culver and co-authors (225) considered to be flawed in that they had “small sample sizes, short periods, and a failure to replicate”, this study which used large sample sizes and longer periods also failed to replicate many prior significant synodic findings and produced a previously unreported association of hospital admissions with the anomalistic month. A limited number of generally small but significant lunar associations, both synodic and anomalistic, were demonstrated.

The significant synodic associations shown were small and, although increases were consistently around FM, these findings were scattered, isolated and inconsistent. FM increases were not significant compared with all lunar variable periods and all lunar variables modelled with the category. Similarly, other models with similar categories (P1, P2, P3 and total) to the significant model were also not significantly different. Consequently these findings are subject to doubt and may be due to unaccounted confounding factors or that they are not reproducable and are chance findings.

The anomalistic admissions models showed significantly decreased admissions at perigee, especially for total admission numbers. Total admissions were significantly less at perigee than both apogee and the interphase for all of the anomalistic lunar variables. In addition, a number of the lower priority admissions anomalistic models, P2 and P3 also demonstrated decreased admissions at perigee. The implication of this association might be that hospital staff can rest

slightly easier around the time of perigee than the rest of the month as a result of between 2% and 12% fewer admissions. This association warrants further investigation.

Since none of the patient consultation categories were significant for the anomalistic cycle, the explanation may be one related to those engaged in the process of admission, the ED doctors, or that fewer patients warranting admission presented at perigee. William Shakespeare's assertion in *Othello* that "It is the very error of the moon, she comes more near the earth than she was wont, and makes men mad" might be true (47). The 'men' apparently under the influence of the moon are the ED doctors and/or patients that sought care. It is doubtful that any lunar effect can clearly identified and conclusively proven considering the array of potential confounding factors. What has been found may just be as a result of this, producing a type 1 error.

The effect sizes of the calendric associations were larger (often much larger) than the lunar associations. If any lunar association exists, it is small and of doubtful impact compared with the calendric variables and would probably not be noticed by staff on duty.

Perhaps, the actual lunacy is the continued belief and research into a 'lunar effect' in the absence of any grossly obvious lunar effect in keeping with the magnitude of the volume of history, literature and belief on the subject. This may in itself be a mark of pure superstition.

Recommendations

Considering the effect sizes of the demonstrated significant lunar associations, no staff increases will be required at any stage of the synodic or anomalistic lunar cycles. Staff increases will be required over weekends and public holidays.
The smaller effect sizes of demonstrated lunar associations compared with those of calendric variables and the possibility of confounding variables not identified suggests further examination of the significant findings.
Further investigation of the previously unidentified association between the anomalistic lunar variables and patient admission to the hospital from the ED would be of interest. Whether the exclusion of all confounding factors is possible is a dilemma.

Perhaps the persistent belief in a lunar effect in the ED is rather attributable to the patient personalities presenting to the ED due to its ready accessibility and the provision of instant gratification. Investigation of the frequency of presentation of personality types to the emergency department may shed light on the feeling that some days or periods are ‘different’. The coincidental presentation of three histrionic patients to the ED at short intervals is perhaps enough to make most believe in an extraneous influence. Research may yield interesting results.

“ In this work when it shall be found that much is omitted,
let it not be forgotten that much likewise is performed.”
– Samuel Johnson.

APPENDIX A University of the Witwatersrand Human Research Ethics Committee (Medical) clearance - original

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Dr Grant D Futcher

CLEARANCE CERTIFICATE	**M10619**
PROJECT	The Assication between the Lunar Cycle and Patterns of Ptients Presentation to the Emergency Department
INVESTIGATORS	Dr Grant D Futcher.
DEPARTMENT	Department of Emergency Medicine
DATE CONSIDERED	25/06/2010
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 28/06/2010 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Prof EEG Lautenbach

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

APPENDIX B University of the Witwatersrand Human Research Ethics Committee (Medical) clearance – amended

University
of the Witwatersrand,
Johannesburg

Human Research Ethics Committee (Medical)
(formerly Committee for Research on Human Subjects (Medical)

Secretariat: Research Office, Room SH10005, 10th floor, Senate House • Telephone: +27 11 717-1234 • Fax: +27 11 339-5708
Private Bag 3, Wits 2050, South Africa

07 December 2011

Dr Grant D Futcher
Department of Emergency Medicine
Faculty of Health Sciences
Medical School
University

Dear Dr Futcher

RE: **Protocol M10619: The association between Lunar Cycle and Patterns of Patients Presentation to the Emergency Department**
Protocol amendment-extension

This letter serves to confirm that the Chairman of the Human Research Ethics Committee (Medical) has reviewed and approved your request to "include an extra year of data-2010" on the abovementioned protocol as detailed in your letter dated 04 November 2011.

Thank you for keeping us informed and updated.

Please accept my apology for the delay in sending this to you

Yours sincerely,

Anisa Keshav
Secretary
Human Research Ethics Committee (Medical0

APPENDIX C South African public holidays

There are 12 recurring public holidays as determined by the Public Holidays Act of the Republic of South Africa, Act 36 of 1994 (6):

New Year's Day (1 January),

Human Rights Day (21 March),

Good Friday (Friday before Easter Sunday),

Family Day (Monday after Easter Sunday),

Freedom Day (27 April), Worker's Day (1 May),

Youth Day (16 June), National Women's Day (9 August),

Heritage day (24 September),

Day of Reconciliation (16 December),

Christmas Day (25 December) and

Day of Goodwill (26 December).

Where a public holiday falls on a Sunday the Monday is observed as a public holiday.

In terms of the Act, additional public holidays may be declared (6) and during this study these included:

01 March 2006 (Local Government Elections) (7),

02 May 2008 (declared holiday) (8) and

22 April 2009 (national and provincial elections) (9).

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