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Article *in* International Journal of Biometeorology · November 2012

DOI: 10.1007/s00484-012-0605-z · Source: PubMed

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Int J Biometeorol (2013) 57:769–774
DOI 10.1007/s00484-012-0605-z

ORIGINAL PAPER

A study on the physical fitness index, heart rate and blood pressure in different phases of lunar month on male human subjects

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Received: 11 August 2011 / Revised: 24 October 2012 / Accepted: 26 October 2012 / Published online: 16 November 2012

Abstract The gravitational pull of the moon on the earth is not the same in all phases of the lunar month, i.e. new moon (NM), first quarter (FQ), full moon (FM) and third quarter (TQ), and as a result the amplitude of tide differs in different phases. The gravitational pull of the moon may have effects on the fluid compartments of the human body and hence the cardiovascular system may be affected differentially in the different phases of the lunar month. In the present study resting heart rate (HR) and blood pressure (BP), physical fitness index (PFI), peak HR and BP immediately after step test, and recovery HR and BP after step test were measured during different phases of the lunar month in 76 male university students (age 23.7±1.7 years). At rest, both systolic and mean arterial BP were ~5 mmHg lower in NM and FM compared to FQ and TQ, but resting HR was not significantly different between phases. Further, peak HR and peak systolic BP after step test were lower (~4 beat/min and ~5 mmHg, respectively) in NM and FM compared to FQ and TQ. PFI was also higher (~5) in NM and FM compared to FQ and TQ. Recovery of HR after step test was quicker in NM and FM compared to that of FQ and TQ. It appears from this study that gravitational pull of the moon may affect the cardiovascular functions of the human body. Moreover, the physical efficiency of humans is increased in NM and FM due to these altered cardiovascular regulations.

Keywords Lunar month · Gravitational pull · Physical fitness index · Cardiovascular function

Introduction

The gravitational pull of the moon on the earth varies in different phases of the lunar month, i.e. new moon (NM), first quarter (FQ), full moon (FM) and third quarter (TQ) (Lieber and Sherin 1972; Myers 1995). As evidence of this variation of lunar gravitational pull the amplitude of ocean tides changes according to the relative position of the moon in its orbit (Monkhouse 1971; Lieber and Sherin 1972; Morgan 2001). The gravitational pull of the moon may have effects on the fluid compartments of the human body (Lieber and Sherin 1972). About 42 l of water (60 % of the body wt.) is present in the human body (Guyton and Hall 2006), and possibly, as with sea water, the body water might generate some sort of tidal wave which has been termed "human tidal wave" or "biological tide" (Thakur et al. 1980; Lieber and Sherin 1972). These authors have used the concept of "biological tide" to explain the lunar influence on human emotional disturbance. Though there is a lot of controversy about the effects of lunar rhythm on human behavior and onset of diseases (Terra-Bustamante et al. 2009; Polychronopoulos et al. 2006; Kollerstrom and Steffert 2003; Biermann et al. 2005; Raison et al. 1999; Yvonneau 1996; Martin et al. 1992), the basic questions of the effects of lunar rhythm on the physiological systems remain unanswered. The generation of any "biological tide" during specific phases of the lunar month will probably affect the activity of the cardiovascular system of the body as it is sensitive to the fluid volume of the body (Fahim 2003). The status of the cardiovascular system may be assessed from the resting parameters such as heart rate and blood pressure but the subtle changes in cardiovascular functions are reflected during cardiovascular stresses like physical exercise (Birch et al.

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2005; Hale 2003; Pickering et al. 1997). The present study has been designed to explore the cardiovascular status by measuring the heart rate and blood pressure in resting condition and during exercise in four phases of the lunar month in humans. The physical fitness index (PFI) which is measured on the basis of cardiovascular changes immediately after exercise has also been studied for the same purpose (Tipton 2003).

Materials and methods

The present study was conducted on 76 male university students (mean age 23.7±1.7 years, height 169.4±6.2 cm, weight 57.6±8.5 kg, BMI 20.03±2.41 kg/m^2). This study was carried out on particular dates and times according to the different phases of lunar month, i.e. in new moon (NM), first quarter (FQ), full moon (FM) and third quarter (TQ). The parameters were measured on the first and second days of each lunar phase between 12:00 noon and 6:00 pm at Vidyasagar University campus (22° 21′N, 87°18′E; 23 m above sea level), Paschim Medinipur, West Bengal, India. Heart rate (HR), blood pressure (BP) and physical fitness index (PFI) were measured in those particular phases of lunar month. It was double blind experiment. The subjects did not know anything about the goal of the experiment and the authors were also blind as the data were coded. Each parameter was measured in 12 phases of three consecutive lunar months in the calendar (February–April 2007). The data obtained from the experiment in the first four phases of the first lunar month were discarded as the subjects took time to be conditioned in the laboratory environment. The range of environmental temperature and humidity for each phase are given in Table 1. Before the experiments the subjects were asked to rest for 1 h while sitting in a quiet and comfortable room (temperature 24±1 °C, humidity 75±10 %). The research was carried out in accordance with the revised guidelines for human experimentation of the Helsinki Declaration of 2000 (Touitou et al. 2004).

Heart rate (HR) and blood pressure (BP)

HR was measured by a 3-lead ECG chest strap (SS2L) (BIOPAC) and BP was measured by an automated auscultatory device (SS19L and SS30L) (BIOPAC), which were both integrated into a BIOPAC MP35 acquisition unit. The measurements were taken according to the BIOPAC Student Lab PRO Manual (2005).

Table 1 Range of environmental temperature (°C) and humidity (%) during those particular phases of lunar month

Lunar phases	Temperature (°C), mean ± SD		Humidity (%), mean ± SD	
	Maximum	Minimum	Maximum	Minimum
NM	35.5±3.1	23.8±3.3	91.5±3.1	59.5±6.5
FQ	36.5±3.0	26.0±2.9	92.3±2.1	64.3±8.5
FM	35.0±3.2	23.3±1.0	89.8±1.9	55.3±3.6
TQ	34.8±2.8	21.8±2.1	89.5±1.9	57.0±5.4

NM new moon, *FQ* first quarter, *FM* full moon, *TQ* third quarter

Physical fitness index (PFI)

The PFI was determined by Harvard step test (Brouha et al. 1943). Briefly, each subject stepped up and down on a 20-in stool for 5 min or until exhaustion (exhaustion is defined as when the subject cannot maintain the stepping rate for 15 s) at an average rate of 30 steps/min. The rate of stepping was determined by metronome. After the 5 min step test, heart beats were measured for 30 s duration at 1–1½ min, 2–2½ min and 3–3½ min recovery. The PFI score was calculated by the following formula:

$$\mathbf{PFI} = \frac{\text{Duration of exercise in seconds}(300\,\text{sec}) \times 100}{\mathbf{2} \times \text{Heart beats at}\left(1 - 1\tfrac{1}{2}\,\text{min} + 2 - 2\tfrac{1}{2}\,\text{min} + 3 - 3\tfrac{1}{2}\,\text{min}\right)\text{after the exercise}}$$

HR and BP after step test

The peak and recovery HR and the peak and recovery BP were measured after Harvard step test. The subject was asked to sit down on a chair at the end of the step test and HR was continuously recorded (for 10 min) while BP was recorded every minute (for 8 min). The peak value of HR was taken immediately after exercise and peak BP was taken within 30 s after the exercise with the help of the Student lab PRO version of the MP35 system (Biopac Student Lab Manual 2005).

Statistical analysis

The mean value of a parameter for a particular phase was calculated from the data obtained on two different days of that particular phase in second and third lunar cycles. The data were analyzed by one-way ANOVA followed by Student-Newman-Keuls multiple comparisons test using GraphPad InStat 3 software. A value of $p<0.05$ was considered as statistically significant. The statistical power (1−β) was calculated at $\alpha=0.05$ (Kothari 2004).

Results

Resting HR and BP

There was no significant difference in resting HR in the different phases of lunar month (Table 2). There were significant differences between four phases of lunar month in systolic BP [F (3, 300)=4.918, $p<0.01$]. The systolic BP in NM and FM were significantly lower ($p<0.05$) than that of FQ and TQ (Table 2). The mean BP was also significantly different among the four phases of lunar month [F (3, 300)=

4.041, $p<0.01$]. Thus the mean BP in NM and FM were significantly lower than that of FQ ($p<0.05$), but not different than that of TQ (Table 2). The diastolic BP did not show any considerable difference among different phases of lunar month (Table 2). The statistical power (1–β) of resting HR and BP analysis are shown in Table 2.

Physical fitness index (PFI)

The PFI was significantly different in four phases of lunar month [F (3, 300)=5.345, $p<0.01$]. The PFI was significantly higher in NM (67.1±0.82) ($p<0.05$) compared to FQ (64.4±0.94) and TQ (63.9±0.87) and also significantly higher in FM (68.1±0.91) compared to FQ ($p<0.05$) and TQ ($p<0.01$) (Fig. 1). The statistical power (1−β) of PFI analysis between different lunar phases (NM vs FQ, NM vs TQ, FM vs FQ and FM vs TQ) are shown in Fig. 1.

HR and BP after step test

The peak HR was significantly different in four lunar phases [F (3, 300)=4.878, $p<0.01$]. The peak HR was significantly lower in NM ($p<0.05$) in comparison to FQ and TQ, and also lower in FM in comparison to FQ ($p<0.05$) and TQ ($p<0.01$) (Table 3). The statistical power (1−β) of peak HR analysis between different phases of lunar month are shown in Table 3.

The peak systolic BP was significantly different in the prominent four phases of the lunar month [F (3, 300)=5.307, $p<0.01$]. The peak systolic BP was significantly lower in NM ($p<0.05$) and FM ($p<0.05$) than that of FQ and TQ (Table 3). There was a significant difference in peak diastolic BP in the four phases of the lunar month [F (3, 300)=2.687, $p<0.05$]. Although significant differences in the means of diastolic BP were present in the four phases of the lunar cycle, the diastolic BP of any two phases did not show any significant difference in post hoc test. The peak mean BP was significantly different among the four phases of the lunar month [F (3, 300)=5.387, $p<0.01$]. The peak mean BP was significantly lower in NM in comparison to FQ ($p<0.05$) and TQ ($p<0.01$), and was also significantly lower in FM than that of FQ ($p<0.05$) and TQ ($p<0.001$) (Table 3). The statistical power (1−β) of peak BP analysis between different phases of the lunar month are shown in Table 3.

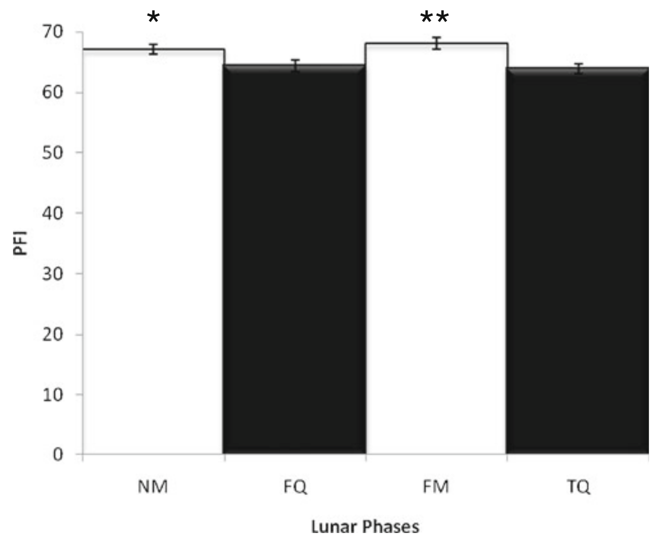

Fig. 1 Changes of physical fitness index (PFI) in four phases of lunar month. Each *bar* represents a mean value, with a vertical SEM bar also shown, n=76. *NM* new moon, *FQ* first quarter, *FM* full moon, *TQ* third quarter. *Significantly higher in NM ($p<0.05$) compared to FQ and TQ. **Significantly higher in FM compared to FQ ($p<0.05$) and TQ ($p<0.01$). Statistical power (1−β): NM vs FQ=0.9756, NM vs TQ=0.9940, FM vs FQ=0.9956, FM vs TQ=0.9978

Table 2 Changes of resting HR and BP in young subjects during the four phases of lunar month. Values: Mean ± SEM, n=76

Lunar phases	Resting heart rate (beats/min)	Resting blood pressure (mmHg)		
		Systolic	Diastolic	Mean
NM	75±0.8	113±1.0*	67±1.3	82±1.1**
FQ	78±1.0	117±1.1	71±1.4	87±1.2
FM	75±0.9	112±1.1*	68±1.4	83±1.2**
TQ	77±1.1	116±1.3	71±1.4	86±1.2

NM new moon, *FQ* first quarter, *FM* full moon, *TQ* third quarter

*Significant at $p<0.05$ compared to FQ and TQ, **Significant at $p<0.05$ compared to FQ

Statistical power (1−β): **HR**: NM vs FQ=0.9756, NM vs TQ=0.8230, FM vs FQ=0.9684, FM vs TQ=0.8230. **Systolic BP**: NM vs FQ=0.9978, NM vs TQ=0.9756, FM vs FQ=0.9978, FM vs TQ=0.9858. **Diastolic BP**: NM vs FQ=0.9858, NM vs TQ=0.9684, FM vs FQ=0.9488, FM vs TQ=0.9010. **Mean BP**: NM vs FQ=0.9968, NM vs TQ=0.9858, FM vs FQ=0.9892, FM vs TQ=0.9684

Table 3 Changes of peak HR and peak BP of young subjects in four phases of the lunar month

Lunar phases	Peak HR (beats/min)	Peak BP (mmHg)		
		Systolic	Diastolic	Mean
NM	133±1.1*	136±1.1*	63±0.7	87±0.7**
FQ	136±1.1	140±1.3	65±0.8	90±0.8
FM	133±0.8**	135±1.3**	63±0.9	87±0.9***
TQ	137±0.8	141±1.3	66±0.9	91±0.8

NM new moon, *FQ* first quarter, *FM* full moon, TQ third quarter

Values presented as mean ± SEM, n=76

*Significant at $p<0.05$ compared to FQ and TQ, **Significant at $p<0.01$ compared to TQ and at $p<0.05$ compared to FQ, ***Significant at $p<0.001$ compared to TQ and at $p<0.05$ compared to FQ

Statistical power (1-β): **HR**: NM vs FQ=0.9488, NM vs TQ=0.9920, FM vs FQ=0.9940, FM vs TQ=0.9978. **Systolic BP**: NM vs FQ=0.9892, NM vs TQ=0.9968, FM vs FQ=0.9940, FM vs TQ=0.9978. **Diastolic BP**: NM vs FQ=0.9684, NM vs TQ=0.9920, FM vs FQ=0.8230, FM vs TQ=0.9356. **Mean BP**: NM vs FQ=0.9956, NM vs TQ=0.9978, FM vs FQ=0.9812, FM vs TQ=0.9956

Recovery of HR from peak value towards resting value was quicker in NM and FM compared to recovery of FQ and TQ. Changes of HR during 10-min recovery period are shown in Fig. 2. The recovery HR was significantly different in the four phases of the lunar month in every minute of the 10-min recovery period [1st minute: F (3,300)=8.373, $p<0.001$; 2nd minute: F (3,300)=6.902, $p<0.001$; 3rd minute: F (3,300)=7.212, $p<0.001$; 4th minute: F (3,300)=5.760, $p<0.001$; 5th minute: F (3,300)=4.496, $p<0.01$; 6th minute: F (3,300)=6.704, $p<0.001$; 7th minute: F (3,300)=5.152, $p<0.01$; 8th minute: F (3,300)=6.748, $p<0.001$; 9th minute: F (3,300)=5.354, $p<0.01$; 10th minute: F (3,300)=9.127, $p<0.001$].

The recovery mean BP did not show any significant change during the recovery period in different phases of the lunar month (Fig. 3).

Discussion

Physical fitness has been assessed by PFI for a long time (Brouha et al. 1943) and has been accepted as a good indicator of physical performance by many investigators in this field (Watkins 1984; Fox et al. 1973; Kenney 1965). It was found in the present study that the value of PFI was increased by ~5 in NM and FM compared to FQ and TQ. As the statistical power of PFI analysis between different phases of the lunar month were near unity (i.e. nearer to 1.0), we can infer that the test is working quite well. Different factors affect PFI, the most important of which are (1) the oxygen supply system to the active muscles, (2) motivation and (3) neuromuscular skill. As the step test requires very little skill, neuromuscular skill is probably not important here. The oxygen supply to the active muscles during the step test depends on the cardiovascular adjustment. Regulation of the cardiovascular system during the step test in different phases of the lunar month may be influenced by gravitational pull of the moon.

The gravitational force is one of the factors controlling the circulatory hemodynamics of the human body. In the human body the blood is pumped into the arterial tree by the contraction of ventricles. In closed-circuit circulation, the blood returns to the heart for further circulation. Gravitational pull can influence the cardiovascular hemodynamics as evidenced by studies in supine and upright/sitting posture on left ventricular end-diastolic volume, left ventricular ejection fraction and heart rate in humans (Poliner et al. 1980; Bevegard et al. 1960). In erect posture blood accumulates more in the lower extremities compared to supine posture (Ewing 1978). Blood from the lower extremities comes back to heart by the respiratory pump and also by the muscle pump during muscular movements of the lower limbs. Thus gravitational pull of the earth slows down the venous return. This conclusion is further supported by the report that the left ventricular end-diastolic volume in the supine position is higher than that of upright posture in rest and exercise with high work load (Poliner et al. 1980). The relative position of the moon and sun on NM and FM are such that their gravitational forces on earth act in a straight line and higher tides in NM and FM are due to the greater gravitational pull of the moon on these days (Monkhouse 1971; Lieber and Sherin 1972; Morgan 2001). Lieber and Sherin (1972) concludes from various medical and nonmedical scientific disciplines that the moon via the effects of its gravitational forces on the humans, causes cyclic changes in water flow among the fluid compartments of the body (intracellular, extracellular, intravascular and intraluminal), as well as changes in total body water, termed as

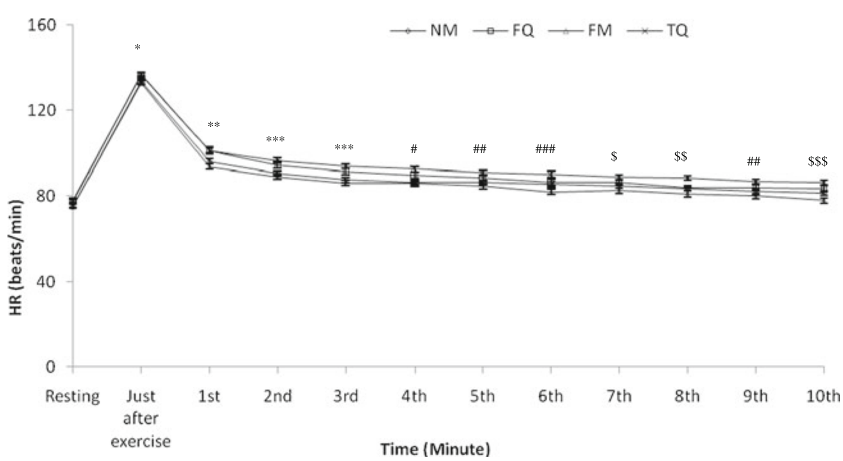

Fig. 2 Changes of resting, peak and recovery HR (BPM) after Harvard step test in young subjects during the four phases of the lunar month. Each *point* represents a mean value and has a vertical SEM bar, $n=76$. *NM* new moon, *FQ* first quarter, *FM* full moon, *TQ* third quarter. * NM vs FQ and TQ, $p<0.05$; FM vs TQ, $p<0.01$ and FM vs FQ $p<0.05$. ** NM vs FQ, $p<0.01$ and NM vs TQ, $p<0.05$; FM vs FQ and TQ, $p<0.001$. *** NM vs TQ, $p<0.01$ and NM vs FQ, $p<0.05$; FM vs TQ, $p<0.001$ and FM vs FQ, $p<0.05$. # NM vs TQ and FM vs TQ, $p<0.01$. ## NM vs TQ, $p<0.05$; FM vs TQ, $p<0.01$. ### NM vs TQ, $p<0.05$; FM vs TQ, $p<0.001$ and FM vs FQ, $p<0.05$. $ NM vs TQ, $p<0.05$; FM vs TQ, $p<0.01$ and FM vs FQ, $p<0.05$. $$ NM vs TQ, $p<0.01$; FM vs TQ, $p<0.001$. $$$ NM vs TQ, $p<0.01$; FM vs TQ, $p<0.001$ and FM vs FQ, $p<0.01$

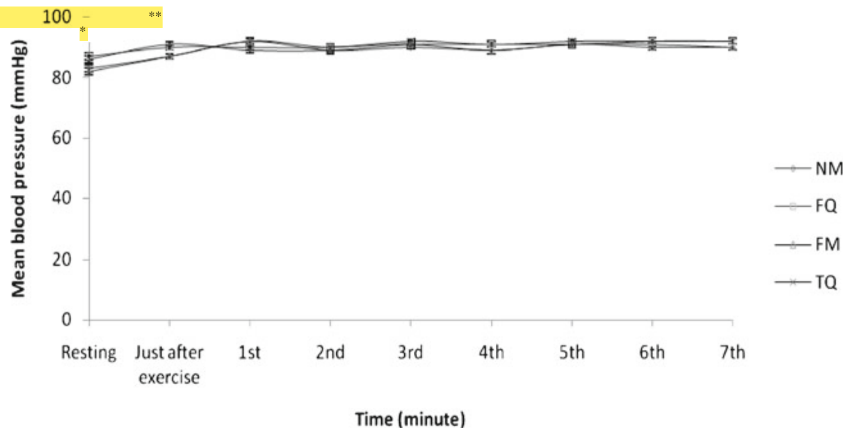

Fig. 3 Changes of resting, peak and recovery mean blood pressure (MBP) (mmHg) after Harvard step test in young subjects during four phases of the lunar month. Each *point* represents the mean value and has a vertical SEM bar, $n=76$. *NM* new moon, *FQ* first quarter, *FM* full moon, *TQ* third quarter. * NM vs FQ, $p<0.05$; FM vs FQ, $p<0.05$. ** NM vs TQ, $p<0.01$ and NM vs FQ, $p<0.05$; FM vs TQ, $p<0.001$ and FM vs FQ, $p<0.05$

"biological tides", and which was stated as "human tidal waves" by Thakur et al. (1980). The venous return may be increased in erect posture in NM and FM compared to other phases due to these "human tidal waves". As the gravitational pull of the moon and sun in the first and third quarters operates at right angles to each other, the 'neap tides' are generated (Morgan 2001). In the human body the venous return on those days can't be favored like that of NM and FM due to the change of gravitational force acting on earth. If the venous return is increased the end diastolic ventricular volume and stroke volumes are becoming higher and a certain amount of cardiac output may be maintained at lower heart rate when stroke volume is higher. This contention may be supported by changes of peak HR immediately after the exercise and recovery HR in different phases of lunar month. It is found from the result that the peak HR was increased by 4 beats/min and recovery period of HR was less in NM and FM compared to FQ and TQ. Peak systolic and mean BP were also decreased by 5 mmHg and 4 mmHg, respectively, in NM and FM compared to FQ and TQ which may be due to the better cardiac adjustment in NM and FM.

The role of the autonomic nervous system in the changes of PFI in NM and FM should also be considered. The stroke volume is not only controlled by the Frank-Starling mechanism but the contractile state of cardiac muscle is an important factor for stroke volume. The contractility of the cardiac muscle is controlled by the autonomic nervous system and by the circulating catecholamines. These neuroendocrine factors may also act on the walls of the blood vessels and thereby may influence the venous return. Though the studies on circulating level of catecholamines in rest and exercise on different periods of lunar month are not available, it has been reported that the autonomic tone was changed in NM and FM compared to FQ and TQ in the Valsalva maneuver (Chakraborty and Ghosh 2012). The higher sympathetic and vagal activities were noted during the Valsalva maneuver in NM and FM compared to that of other phases. Thus an altered autonomic activity may facilitate venous return from lower extremities and may explain lower peak HR and peak systolic BP during exercise. Thus a combined effect of the Frank-Starling mechanism and autonomic activity is probably causing higher PFI in NM and FM compared to other periods.

The PFI also depends upon the change of motivation or behaviour. One of the factors influencing the motivation of animals and humans may be the different phases of lunar month. There are many reports that "biological tides" may cause physical, physiological and biochemical changes which create a qualitative difference in the human body, influencing behaviour like self-poisoning (Thakur et al. 1980), crime (Thakur and Sharma 1984; Schafer et al. 2010) and violence (Lieber and Sherin 1972).

The "human tidal waves" in NM and FM influence the resting systolic BP and mean BP as evidenced by lower values of these parameters in those phases. Systolic BP and mean BP are influenced by the stroke volume and / or peripheral resistance which are regulated by the fluid volume and the autonomic tone. The fluid volume of the body in different phases of lunar month was not measured in the present study and this information is not available in the literature. However, it is mentioned that autonomic tone is changed during the Valsalva maneuver in NM and FM compared to that of FQ and TQ (Chakraborty and Ghosh 2012). This altered autonomic activity is probably one of the underlying causes of the changes of resting systolic BP and mean BP. The changes of autonomic tone in reflex condition (i.e. Valsalva maneuver) appear to be more compared to the resting condition as the resting HR is not altered in NM and FM compared to that of other phases, like that of peak HR during exercise.

There are some limitations to this study. (1) Only male subjects were selected for the experiment; females were not selected because the physiological conditions of females may change according to their menstrual cycle (Dunne et al. 1991; Freedman and Girgis 2000; Kuwahara et al. 2005). The average length of the menstrual cycle is the same as that of the lunar synodic cycle, and menstruation has been found to occur preferentially at one of the prominent phases of the lunar month (Law 1986; Cutler et al. 1987; Zimecki 2006). So, effects of lunar phases may be affected by other physiological factors in females. (2) Only young subjects were included here, but the physiological condition of older subjects may also be affected by lunar phases. (3) The fluid volume or hydration status of the subjects in each lunar phase was not measured here. (4) Structure of the heart and the size of blood vessels were not measured in this study. (5) The hormonal status of the subjects was also not measured during the study period.

Considering all of these things, the present study indicates that the cardiovascular dynamics are influenced by the lunar cycle, and the factors regulating the cardiovascular system are influenced by the altered gravitational force of the moon in different phases of the lunar cycle. The exercise-induced cardiovascular changes are more prominent than in the resting condition. Moreover, the physical efficiency of humans is increased in NM and FM due to these altered cardiovascular regulations.

Acknowledgements As part of the study was carried out in the Department of Human Physiology, Vidyasagar University, the authors would like to acknowledge this Department for use of its facilities.

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