# THE IMPACT OF LUNAR RHYTHMS ON CROSS-COUNTRY SKIING ATHLETE'S LOCOMOTOR PERFORMANCE

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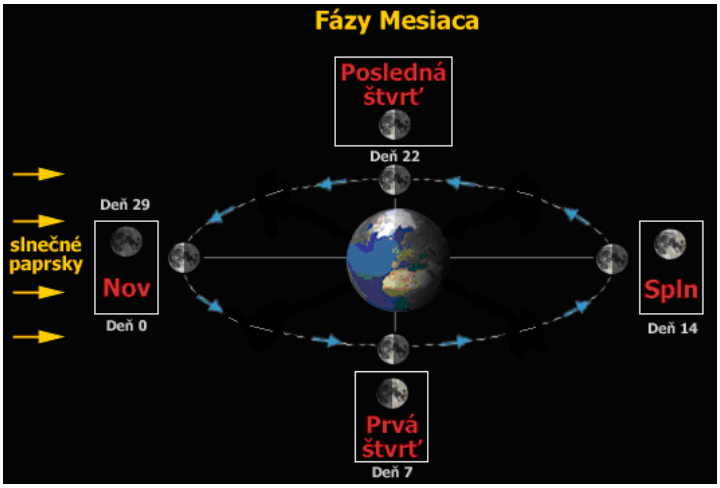
biological rhythms, lunar rhythms, locomotor performance

The aim of the study was to determine the effects of lunar rhythms on the course of oscillation of locomotor performance of a cross-country skiing athlete. The object of the research was a member of the Academic National Team, a student of Physical Education and Sports, Faculty of Arts, Matej Bel University in Banska Bystrica. She was born on August 4, 1991, her body height was 175cm and body weight was 65kg. She has been cross-country skiing since 1997. The diagnostics were performed by five tests during six lunar cycles from July to December RTC 2013/2014. The following test were used: the Ruffier test, 30m sprint, CrossFit sit-ups, the Home Step Test and Medicine Ball Throw (2kg). Based on the results of the research, we found that in the first phase of the lunar rhythm the proband achieved the best results in four tests – the Ruffier test, 30m sprint, sit-ups, and Home Step Test. In the dynamic strength of the upper limbs, we have recorded the best results in the third phase of the lunar rhythm. Based these findings, we conclude that the phases of the lunar rhythm are suitable for the development of the individual locomotorabilities.

## INTRODUCTION

Mankind has always been paying attention to phases of the Moon. Rigorous observation of nature, the world of animals and plants made, out of many of our ancestors, the masters of the right time. Tasks, such as wood chopping, cooking, eating, cutting of hair, gardening work, fertilization or surgery are affected by the Moon. Even plants harvested at the right time are more potent than those harvested some other time. Many other natural phenomena, such as tides, the alteration between daylight and night during the day, change of the seasons, weather, menstrual cycles and childbirth are related to the path of the Moon. Over time, some physiological functions in human have begun to be observed and recorded, for example the effects of sleep on body temperature, health and its relationship to light frequency, studying oscillation of physical and psychological performance of human during daytime (Jančoková, 2013). The basis of life establishment on the Earth is formed by rhythmicity and is one of the main features of living systems.

Alteration of lunar phases is caused by the Sun always illuminating different parts of the Moon (Figure 1). During new Moon, the dark side of the Moon is facing the Earth and the Moon is not visible from the Earth. In the first quarter, half hemisphere of the Moon is visible (similar to letter D). Further, the illuminated part of the Moon is increasing. During full moon, the entire hemisphere facing the Earth is illuminated. It shines all night, because it is facing directly the Sun. Then, the Moon wanes again. Last quarter – the Moon "reverses" to the final quarter, in the form of "C". It appears in the morning sky heading back to the new moon, which marks the beginning of a new cycle (Wikipedia).




Fibure 1 Phases of the Moon (amended accoring to www.meteo.sk)

In general, according to Homolka et al. (2010) lunar external rhythms are applied in synchronization of exogenous biorhythms especially in invertebrates, while in higher organisms it is discussed whether residuals of the direct impact of lunar rhythms still persist in them. This is the case of, for example human sexual cycles. Also the average circa 28-day period of the female menstruation cycle has a duration within the range of the synodic month (from 27.3 to 29.5 day). It is impossible to reject that during development of various species were the real sexual cycles, including the human cycle, synchronized with lunar phases; according to other authors, it can be a mere coincidence. It is believed that moonlight can the signal for tuning of the lunar rhythm (Jančoková, 1998).

In the research by Amina (2006), in which the author examined the impact of changes in body temperature of the circadian rhythm on locomotor and psychological performance, he examined the impact of the lunar rhythm on performance, as a partial task. He monitored locomotor performance by the static strength test of the upper limbs, psychological performance was evaluated by non-standard questions and by filling out numerical series (Sudoku). In the results he indicates that he has not found correlation with the full-moon phase compared to the other days. The limitation of the research was, however, that he did not monitor the whole period of the lunar rhythm but only 10 days peaking in the phase of the full moon, and the number of probands was also too low to make general conclusions.

Roveský et al. (1998) examined whether lunar rhythms occur in a sequence of 74 cases of articular chondrocalcinosis attacks (a congenital metabolic disorder with crystallization of calciumpyrophosphatedihydrate in articular cartilage) registered between 1954 and 1995.

He stated that attacks of chondrocalcinosis may be more associated with natural and heliogeophysical factors (geomagnetic activity, lunisolar gravity) and less with social factors compared to another disease – gout. The coefficient of determination of gout with synodical month was 0.969 peaking around the full moon and new moon (Mikulecký et al. 1996).

## METHODOLOGY

The proband currently operates in Ski Team JASE Látky (STJL) and the coach is a former member of the National Cross Country Ski Team Bc. M. K. In the preparatory period RTC 2013/2014, she trained 5-6x a week in two stages.

Table 1 shows the phases of the lunar rhythm and the testing dates. The testing was performed under equal conditionals in the sports complex of an elementary school in Hriňová, with the assistance of coach M.K. The testing was performed between 9:00AM and 11:00AM.

Table 1 Phases of the lunar rhythm and dates of the testing (www.polovacka.com)

| Lunar Rhythms (Year 2013) | I. Phase (New Moon) | II. Phase (First Quarter) | III. Phase (Full Moon) | IV. Phase (Last Quarter) |
|---|---|---|---|---|
| **July** | 7.7.2013 | 14.7.2013 | 22.7.2013 | 29.7.2013 |
| **August** | 6.8.2013 | 13.8.2013 | 20.8.2013 | 28.8.2013 |
| **September** | 4.9.2013 | 11.9.2013 | 19.9.2013 | 26.9.2013 |
| **October** | 4.10.2013 | 11.10.2013 | 18.10.2013 | 26.10.2013 |
| **November** | 2.11.2013 | 9.11.2013 | 17.11.2013 | 25.11.2013 |
| **December** | 2.12.2013 | 9.12.2013 | 16.12.2013 | 24.12.2013 |

The testing battery consisted of five tests: the Ruffier test, 30m sprint, CrossFit sit-ups – sit in 30 seconds, the Home Step Test and Medicine Ball Throw (2kg) (Šimonek, 2012). The individual results were recorded on a tracking sheet.

**The Ruffier test** – determines the functional status of the cardiovascular system and the readiness of the organism to load.

*Tools*: metronome, sport tester, stopwatch, bench.

*Procedure*:

Step 1 – after about 5 minutes of relaxation in seated position, we recorded SF – S1 at rest.

Step 2 – 30 squats for 45 seconds, followed by recording SF – S2.

Step 3 – 1 minute relaxation in seated position and recording – S3.

*Assessment*: according to the formula: **RI = [(S1 + S2 + S3) - 200]/10**

Table 2 Index assessment of the Ruffier test (www.aos.sk/struktura/katedry/ruffier).

| Ruffier test Index | Assessment |
|---|---|
| below 3,0 | excellent functional status |
| 3,1 - 7,0 | good functional status |
| 7,1 - 12 | average functional status |
| 12,1 - 15,0 | below average functional status |
| above 15,1 | poor functional status |

**CrossFit sit-ups (30sec.)** – evaluates dynamic and endurance strength of abdominal and hip-thigh muscles.

*Tools*: mat.

*Procedure*: supine starting position, legs slightly bent, feet on the mat, arms next to the body, trunk movement forward and back through the abdominal muscles in 10cm range marked on the mat.

*Assessment*: number of repetitions within 30 seconds.

**The Home Step Test** – evaluates cardiovascular endurance.

*Tools*: stair step, 30.5cm high platform, stopwatch, sport tester.

*Procedure*: 3-minute ascents and descents in a four-beat rhythm. After completion, SF is recorded standing after 1 minute.

*Assessment*: according to indicative standards given in Table 2. The lower SF value after load, the higher aerobic endurance.

Table 3 Assessment of cardiovascular endurance

| Age | 18-25 | 26-35 | 36-45 | 46-55 | 56-65 | 65+ |
|---|---|---|---|---|---|---|
| Excelent | < 85 | < 88 | < 90 | < 94 | < 95 | < 90 |
| Good | 85-98 | 88-99 | 90-102 | 94-104 | 95-104 | 90-102 |
| Above Average | 99-108 | 100-111 | 103-110 | 105-115 | 105-112 | 103-115 |
| Average | 109-117 | 112-119 | 111-118 | 116-120 | 113-118 | 116-122 |
| Below Average | 118-126 | 120-126 | 119-128 | 121-129 | 119-128 | 123-128 |
| Fair | 117-128 | 118-128 | 120-130 | 123-132 | 121-129 | 121-130 |
| Poor | > 140 | > 138 | > 140 | > 135 | > 139 | > 134 |

**30m Sprint** – evaluates the level of speed capability

*Tools:* running track, measuring tape, stopwatch.

*Procedure:* full-standing start on the command “On your marks – Ready – Set – Start”.
*Assessment*: time in seconds (sec.), accuracy of time-recording 0.1sec.

**Medicine Ball Throw** – evaluates the level of explosive strength of upper limbs and trunk.
*Tools:* medicine ball (2kg), measuring tape.
*Procedure:* standing with feet shoulder width apart, holding the ball with both hands behind the head, repeatedly perform three attempts.
*Assessment:* distance from the throwing mark to the point of impact. The longest throw in centimeters (cm) of three attempts is measured.

When processing the results of the study, we used quantitative and qualitative methods. Arithmetic mean (x) and standard deviation (SD) were the descriptors of descriptive statistics (SD). To determine the significance of differences between the individual phases of the lunar rhythm, we used the non-parametric Friedman’s test at the 5% level of significance ($p<0.05$). MedCalc (version 13.2.2.0) software was used. Qualitative methods (analysis, synthesis, induction, deduction and comparison) were used when interpreting the results and when looking for causalities of the studied phenomena.

## RESULTS

The performance of the cardiovascular system and the readiness of organism to load was evaluated by the Ruffier test. The results obtained are presented in Table 4. According to the Ruffier test index (Table 1) we note that J.G. achieved in all four phases of the lunar rhythm same level of functional state of the body – good functional status. Nadir (index value of 3.5) was recorded in October and November in the I. Phase of the lunar rhythm. The acrophase of the functional state of the athlete’s organism was recorded in July in the IV. Phase of the lunar rhythm. We assume that this was caused by a preexisting disease. After summarizing of the results and on the basis of the curve we conclude that the most appropriate phase for the performance of the cardiovascular system and readiness of the organism to load is the I. Phase, conversely, the most inconvenient is the IV. Phase of the lunar rhythm.

Table 4 Results of **the Ruffier test** in phases of the lunar rhythms of J.G.

| Lunar Phases (rok 2013) | I. Phase (New Moon) | II. Phase (First Quarter) | III. Phase (Full Moon) | IV. Phase (Last Quarter) |
|---|---|---|---|---|
| **July** | 3,9 | 4,2 | 4,5 | 4,9 |
| **August** | 3,8 | 4,0 | 4,2 | 4,5 |
| **September** | 3,6 | 3,8 | 4,0 | 4,0 |
| **October** | 3,5 | 3,6 | 3,9 | 3,9 |
| **November** | 3,5 | 3,7 | 3,8 | 3,9 |
| **December** | 3,7 | 3,6 | 3,8 | 3,9 |
| **x** | **3,67** | **3,82** | **4,03** | **4,18** |
| **min** | **3,5** | **3,6** | 3,8 | 3,9 |
| **max** | **3,9** | 4,2 | 4,5 | 4,9 |
| **SD** | **0,16** | **0,24** | **0,27** | **0,42** |

**Legend:**
x – arithmetic mean
min – minimum value
max – maximum value
SD – standard deviation

The findings are also presented in Figure 1. The curve exhibits, from I. Phase to IV. Phase, a gradual decline in the level of functional ability of the body, as recorded by a simple functional test. On that basis, we conclude that the I. Phase is the most appropriate and most important for developing performance of the cardiovascular system and readiness of the organism to load. From the data of J.G.’s health we found that the value of the index in the 1$^{st}$ testing in the IV. Phase of the lunar rhythm could have been affected by the mentioned illness. However, we conclude that it may have not had such a considerable impact because all values were the worst in the IV. Phase of the lunar rhythm. It is also documented by the level of the standard deviation of the individual lunar rhythm phases. The result of the Friedman's non-parametric test showed that there are significant differences (p<0.05) between the individual phases.

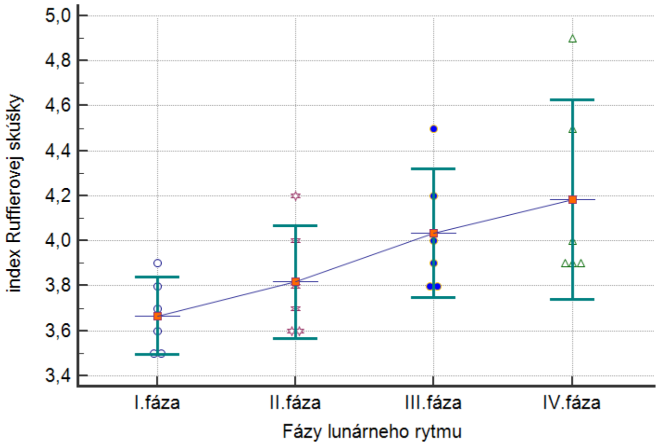



Figure 1 The Lunar rhythm index of the Ruffier test in proband J.G.

**Test T (2) CrossFit sit-ups**

By testing, we examined the dynamic and endurance strength of abdominal and hip-thigh muscles in 30-second intervals. The results are presented in Table 5 and Figure 2.

Table 5 Results of the CrossFit sit-ups test of J.G.'s lunar rhythm (number of repetitions)

| Lunar Rhythm Phases | I. Phase | II. Phase | III. Phase | IV. Phase |
|---|---|---|---|---|
| **July** | 23 | 23 | 21 | 22 |
| **August** | 23 | 22 | 21 | 22 |
| **September** | 23 | 23 | 22 | 22 |
| **October** | 23 | 23 | 23 | 22 |
| **November** | 23 | 23 | 23 | 22 |
| **December** | 23 | 23 | 23 | 22 |
| **x** | **23** | **22,83** | **22,17** | **22** |
| **min** | **23** | **22** | **21** | **22** |
| **max** | **23** | **23** | **23** | **22** |
| **SD** | **0** | **0,41** | **0,98** | **0** |

**Legend:**
x – arithmetic mean
min – minimum value
max – maximum value
SD – standard deviation

Nadir was again recorded in the I. Phase of the lunar rhythm with average performance at 23 ±0. This means that in the I. Phase of the lunar rhythm (from July to December 2013) J.G. achieved identically 23 repetitions, in II. Phase she achieved average performance of 22.83. In the III. and IV. Phase of the lunar rhythm, we recorded a gradual loss in performance to the level of 22 repetitions – acrophase. In the III. Phase, we also recorded two of the worst results from all the testing (21 repetitions).

In Figure 2 we see a decreasing curve, which represents the decline from the best to the worst phase. The curve of J.G. shows a slight decline from the I. to the II. Phase and from the III. Phase to the IV. Phase. A slightly greater decline was recorded from the II. to the III. Phase, where the average performance decreased from 22.83 to 22.17, which already is a significant difference. From the given curve, we assume that for improved performance of the dynamic and endurance strength of the abdominal and hip-thigh muscles is the I. Phase the most appropriate, in which J.G. achieved the best results in all months of testing, whereas the least desirable is the IV. Phase of the lunar rhythm. The lowest standard deviation was recorded two times ±0 in the I. and the IV. Phase. The results of the Friedman's non-parametric test showed that there were significant differences ($p<0.05$) among the individual phases.

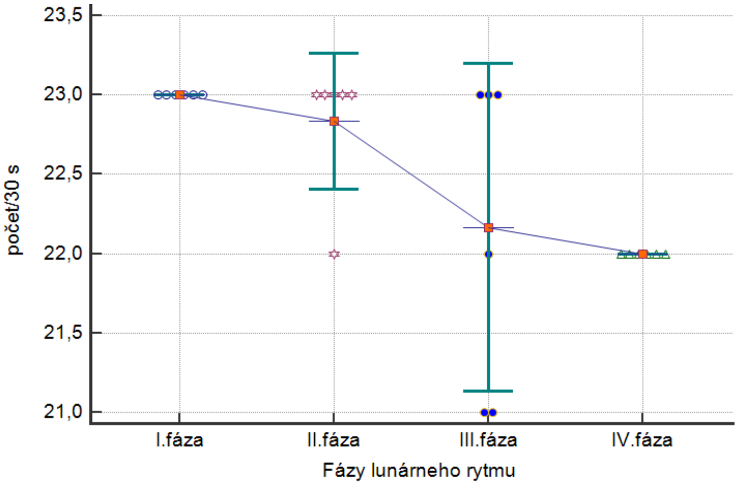



Figure 2 Lunar rhythm of CrossFit sit-ups (number of repetitions)

**Test T (3) Home Step Test**

By this test, we examined the level of cardiovascular endurance and aerobic fitness. J.G. achieved excellent heart rate, since her performance in neither phase did not exceed 85 SF (heart rate), which is the threshold of excellent heart rate. Although results across the individual phases varied, they never exceeded the excellent level of heart rate. The lower the heart rate values after testing, the level of aerobic fitness was higher (Table 6). Nadir was again recorded in the I. Phase of the lunar rhythm (72.83 ±0.75). the Acrophaes was recorded in the III. Phase with average performance at level of 78 SF. In month of July during this phase, J.G. achieved the worst result of 82 SF.

Table 6 Results of the Home Step Test of J.G.'s lunar rhythm (number of repetitions)

| Moon Phases | I. Phase | II. Phase | III. Phase | IV. Phase |
|---|---|---|---|---|
| **July** | 72 | 75 | 82 | 79 |
| **August** | 73 | 75 | 79 | 78 |
| **September** | 72 | 74 | 75 | 76 |
| **October** | 73 | 74 | 77 | 75 |
| **November** | 74 | 75 | 76 | 78 |
| **December** | 73 | 76 | 79 | 77 |
| **x** | **72,83** | **74,83** | **78** | **77,16** |
| **min** | **72** | **74** | **75** | **75** |
| **max** | **74** | **76** | **82** | **79** |
| **SD** | **0,75** | **0,75** | **2,53** | **1,47** |

**Legend:**
x – arithmetic mean
max – maximum value
min – minimum value
SD – standard deviation

Based on the curve in Figure 3, we conclude that for the performance of the cardiovascular endurance and aerobic fitness is the most appropriate the I. Phase of the lunar rhythm, when J.G. achieved the best average performance of 72.83 and also two of the best performance readings among all four phases. Conversely, the least desirable if the III. Phase of the lunar rhythm. The results of the Friedman's non-parametric test showed that there were statistically significant (p<0.05) differences between the individual phases.

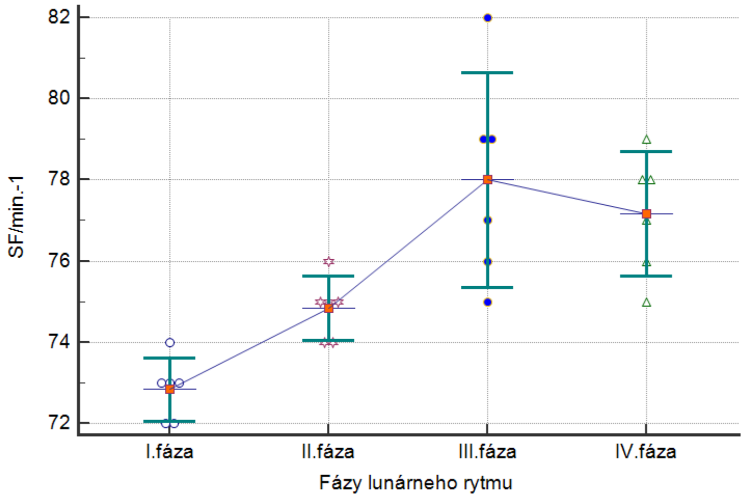



Figure 3 Lunar rhythm of the Home Step Test of J.G. (SF)

**Test T (4) 30m Sprint**

By the test we assessed the level of running speed capability. Table 7 implies that J.G. recorded fluctuating performance in the speed of running. Nadir was again established in the I. Phase of the lunar rhythm (5.64sec.). Also the individual performance in this phase were among the best. Subsequently, J.G. achieved a decline in performance to the average level of 5.99sec., and averge performance of 5.77sec. in the III. Phase, and the best result of 5.54sec. in July. We found the acrophase of the lunar rhythm in the IV. Phase (6.00sec.).

Table 7 Results of the 30m Sprint of J.G.'s lunar rhythm (sec.)

| **Moon Phases** | **I. Phase** | **II. Phase** | **III. Phase** | **IV. Phase** |
|---|---|---|---|---|
| July | 5,52 | 6,11 | 5,54 | 6,07 |
| August | 5,48 | 6,01 | 5,60 | 6,03 |
| September | 5,50 | 5,74 | 5,72 | 5,83 |
| October | 5,75 | 5,80 | 5,89 | 5,90 |
| November | 5,85 | 5,93 | 6,03 | 6,00 |
| December | 5,75 | 5,90 | 5,83 | 6,15 |
| **x** | **5,64** | **5,92** | **5,77** | **6,00** |
| **Min** | 5,48 | 5,74 | 5,54 | 5,83 |
| **max** | 5,85 | 6,11 | 6,03 | 6,15 |
| **SD** | **0,16** | **0,14** | **0,18** | **0,12** |

**Legend:**
x – arithmetic mean
max – maximum value
min – minimum value
SD – standard deviation

Based on the presented results in Figure 4, we conclude that for the performance of speed capabilities of the organism is the I. Phase optimal, whereas the IV. Phase of the lunar rhythm is the least suitable. The results of the Friedman's non-parametric test showed that there were statistically significant ($p<0.05$) differences between the individual phases.

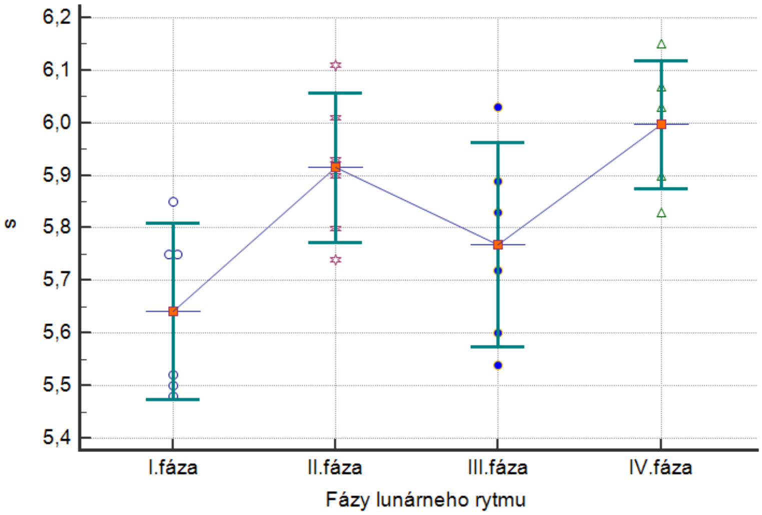



Figure 4 Lunar rhythm of 30m Sprint of J.G. (sec.)

Table 8 Results of the Medicine Ball Throw test of the lunar rhythm of J.G. (cm)

| Moon Phases | I. Phase | II. Phase | III. Phase | IV. Phase |
|---|---|---|---|---|
| **July** | 754 | 770 | 820 | 811 |
| **August** | 755 | 786 | 800 | 800 |
| **September** | 765 | 780 | 807 | 791 |
| **October** | 785 | 773 | 795 | 812 |
| **November** | 785 | 790 | 787 | 800 |
| **December** | 779 | 813 | 800 | 790 |
| **x** | **771** | **785** | **802** | **801** |
| **min** | 754 | 770 | 787 | 790 |
| **max** | 785 | 813 | 820 | 812 |
| **SD** | **140** | **160** | **110** | **90** |

**Legend:**
x – arithmetic mean
max – maximum value
min – minimum value
SD – standard deviation

**Test T (5) Medicine Ball Throw**

With this test we examined the level of explosive capability of upper limbs and trunk. The results are presented in Table 8. Exactly at this level of capability we first found the acrophase of the lunar rhythm in the I. Phase with average performance of 771cm. Nadir was detected in the III. Phase with average performance of 802cm.

The achieved results are, for better depiction, presented also in Figure 5. The performance curve shows increasing tendency from the I. to the III. Phase. The average performance soared from 771cm to 802cm. In the IV. Phase, we recorded a decline in the average performance of 1cm. On this basis, we conclude that for the performance of explosive capability of the upper limbs and trunk is the III. and IV. Phase suited the most and the I. Phase of the lunar rhythm suitable the least. The results of the Friedman's non-parametric test showed that there were statistically significant ($p<0.05$) differences between the individual phases.

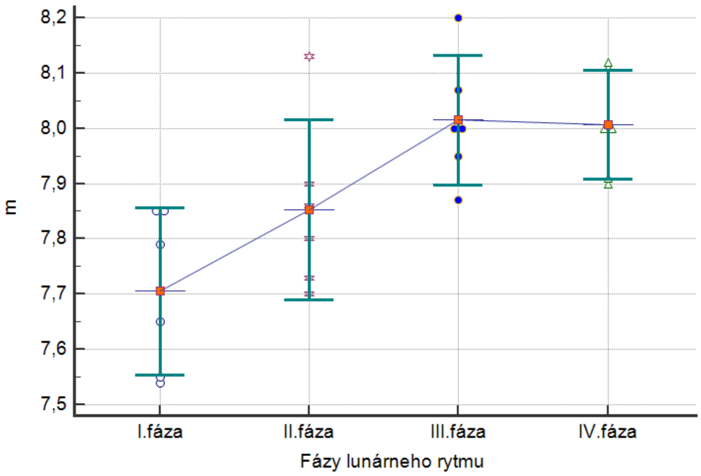



Figure 5 Lunar rhythm of Medicine Ball Trow of J.G. (m)

**DISCUSSION and CONCLUSION**

The aim of the study was to investigate the effect of lunar rhythm on the course of oscillations of locomotor performance of cross-country skiing female athlete in the preparatory period RTC 2013/2014. Based on the distribution of the lunar rhythm phases, we determined the days of testing. The object of the research was J.G., academic representative in cross-country skiing. The testing was performed on the promises of an elementary school in Hriňová during a six-moth period. Repeatedly, we performed measurements of physical performance in the different phases of the lunar rhythm. The locomotor performance was diagnosed by five tests: the Ruffier test, 30m sprint, CrossFit sit-ups, the Home Step Test and Medicine Ball Throw (2kg). The level of locomotor performance varied at each stage of the lunar rhythm. By analyzing the achieved results, we found that a curve with different amplitude and with an uneven distribution of acrophases and nadirs exists in the area of locomotor performance. Overall, we consider the I. Phase the most performance-favorable phase of the lunar rhythm. In this phase, we recorded the best results in the proband in the tests T (1), T (2), T (3) a T (4). In the test T (1), the curve depicts a gradual decline in performance from the I. Phase to the IV. Phase of the lunar rhythm.

Compared to the work of Mojžiš (2011) who considers the I. Phase the most favorable phase of the girls' lunar rhythm, our results match significantly. The least favorable phase, according to Mojžiš (2011) is the IV Phase of the lunar rhythm, which is a comparable result with our study. However, practicing only a couple of days a month around the I. Phase would, for active and elite athletes be ineffective because they would not improve their performance this way. We can, however, take into account the individual results and utilize them in the training process so that the muscle group with deficit that is most negatively reflected in the performance, would be trained the most during the most favorable phase. We recommend to take different oscillation of physical and mental performance in different phases of the lunar rhythm into account. One of the options of streamlining the training process for athletes we see in utilization of natural biological rhythmicity of the organism and its interactions with the external environment. Our research of the lunar rhythms, we aimed to contributing with novel findings in the field of biological rhythms, as multi-day rhythms are still little explored.

The external environment affected by several external factors lined to exogenous rhythms (lunar in our case) cause in the human organism arrangement of endogenous functions in a way that the organism is able to maintain the homeostasis state in under any conditions. Additionally, to achieve performance and resistance to all kinds of strain the body is exposed to. It is therefore vital exposing the body to a sufficient amount of stimuli, which it gradually adapts to and builds protective mechanism. On the contrary, in the absence of a sufficient amount of stimuli from the external environment, disorders in the body occur, which have negative impact on the overall locomotor performance. In our research, we investigated the effects of the lunar rhythm, as the complex biological rhythm on locomotor and psychological performance in schoolchildren. It was not in our interest to deny or not to deny the myths and speculation about the effects of the full moon, or another phase of the Moon on humans.

The study is part of a solution of a grant task (research) VEGA 1/0795/15 Biorhythms, an important lifestyle phenomenon of the population

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