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Space Weather Phenomena Impact on Human Physiological Parameters: Data from Rome

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1. Background-Aim

Space Weather Phenomena Impact on Human Health

The study of the effects of the geophysical activity on human health was first developed during the 20th century when the Russian biophysicist Dr. A.L. Chizhevsky founded the field of 'Heliobiology'

(Zhadin, 2001; Zenchenko et al., 2024)

Modern fields of science that focuses on the influence of geophysical activity on human health and especially pathological diseases

Biogeomagnetics

The effect of Space Weather parameters, through variations of the geomagnetic field, on the pathological state of various diseases, traffic accidents, reaction time, etc.

(Dorman et al., 2001)

Clinical Cosmobiology

The relationship between the level of physical activity and the mortality/morbidity from various diseases, e.g. cardiac arrhythmias, strokes, myocardial infractions and other cardiovascular diseases

(Stoupel, 2006)

Heliobiology or Cosmobiology/Astrobiology

The effect of solar activity on living organisms and especially the human physiological state

(Palmer et al., 2006; Babayev, 2008)

2. Materials & Methods

Data

Medical Data

- A number of 2050 daily averaged values of heart rate (HR, beats per minute - bpm), registered for a group volunteers during their medical examinations in the Polyclinico Tor Vergata, Rome, Italy
- These data were obtained using a Holter Electrocardiogram (Papailiou et al., 2023) and refer to men (759) and women (788) aged from 5 to 96 years old
- The analysis covers the time period from 24 April 2003 until 12 May 2004
- All volunteers provided information about their general medical and psycho-physiological state before obtaining any data.

Geomagnetic activity (GMA) data

- Geomagnetic Index Dst (nT) (World Data Centre for Geomagnetism, Kyoto)
https://wdc.kugi.kyoto-u.ac.jp/dstae/index.html
- Geomagnetic Index Ap *(*German Research Center for Geosciences, GFZ)
https://www.gfzpotsdam.de/en/section/geomagnetism/dataproductsservices/geomagnetic-kp-index

Cosmic ray intensity (CRI) data

- Daily, pressure and efficiency corrected CRI data (counts/sec)(Rome Cosmic Ray Station - Studio Variazioni Intensità Raggi Cosmici: S.V.I.R.CO., effective vertical cutoff rigidity 6.27 GV)
http://www.nmdb.eu

2. Materials & Methods

Geomagnetic activity data

GMA was organized into five levels of intensity, according to the Dst- and Ap-index daily values

Activity	Dst / Ap levels	Dst-index values (nT)	Number of measurements	Ap-index values	Number of measurements
Quiet	I0	Dst $\geq$ 0	139	Ap < 8	210
Minor	I	−20 < Dst < 0	318	8 $\leq$ Ap < 15	204
Moderate	II	−50 < Dst $\leq$ −20	235	15 $\leq$ Ap < 30	220
Strong	III	−100 < Dst $\leq$ −50	28	30 $\leq$ Ap < 50	73
Severe	IV	Dst $\leq$ −100	11	Ap $\geq$ 50	24

(Dimitrova et al., 2009; Mavromichalaki et al., 2012)

Cosmic ray intensity data

Cosmic ray activity was organized into five levels of intensity, according to the CRI, % values

Intensity	CRI levels	CRI, %	Number of measurements
Severe decreases	-3	-17 $\leq$ CRI $\leq$ -11	4
Major decreases	-2	-11 < CRI $\leq$ -6	15
Moderate decreases	-1	-6 < CRI $\leq$ -1	291
Quiet	0	CRI = 0	92
CRI increases	1	1 $\leq$ CRI $\leq$ 3	329

(Papailiou et al., 2023)

2. Materials & Methods

Statistical Method

1. Analysis of Variance (ANOVA) (Iacobucci, 2016)

The ANOVA method tests the impact of the *factors* or *independent variables*, i.e. Dst, Ap and CRI levels on the *dependent variable*, i.e. HR

The dependent variable values (i.e. HR) follow a normal distribution (Shapiro–Wilk test of normality: W = 0.993620).

- ***Null hypothesis:*** for every different level of geophysical activity (Dst level, Ap level and CRI level), the mean values of the dependent variable under study (HR) are the same
- ***Alternative hypothesis:*** the geophysical activity levels affect the physiological parameter

The statistical significance level will ultimately determine which of the two hypotheses is valid.
The level of statistical significance is set at $p < 0.05$ by the software

2. Chree analysis, i.e. the superimposed epochs method (Forbush, 1938)

This method evaluates the temporal distribution of a parameter (in this case, HR) during the development of an event (i.e., geomagnetic storm or CRI decrease).

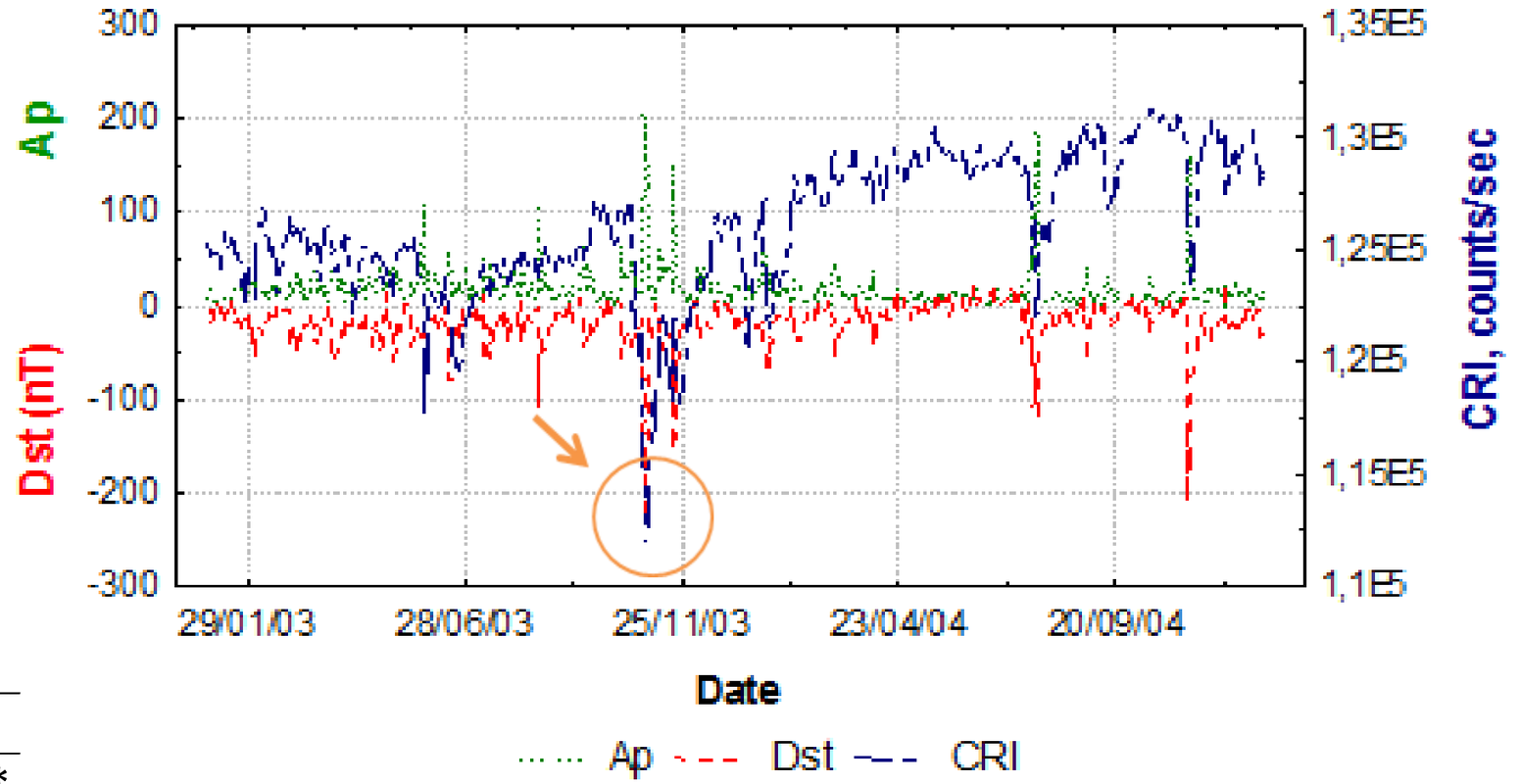
The effect of the geophysical activity on the physiological parameter up to three days before and three days after geomagnetic storms or CRI variations is examined

3. Results

Geophysical Activity

- Declining phase of Solar Cycle 23
- Late October/November 2003:
  "Great Halloween Solar Storms"

*- **30-31/10/2003**: severe CRI decrease (-17%) and geomagnetic storm (Dst = -221nT and Ap = 191)*



Daily Dst-index, nT (red dashed line), Ap-index (green dotted line) and CRI, counts/sec (blue punctuated line) for the time period from 1 January 2003 until 31 December 2004

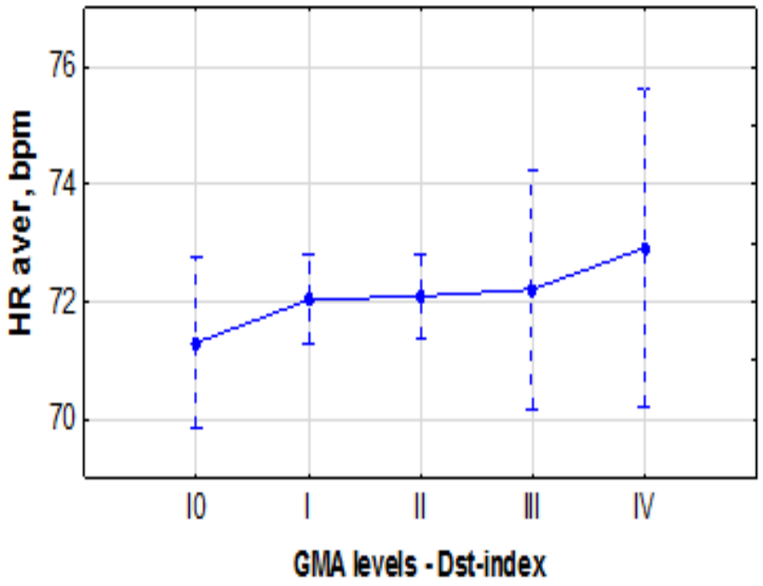
Days	Dst	Ap	CRI
-3	0.36972	0.56033	0.01596*
-2	0.43717	0.42622	0.14030
-1	0.74530	0.23454	0.05954
0	0.83491	0.79509	0.01172*
+1	0.97541	0.01415*	0.02898*
+2	0.90324	0.64736	0.53414
+3	0.81379	0.58817	0.06004

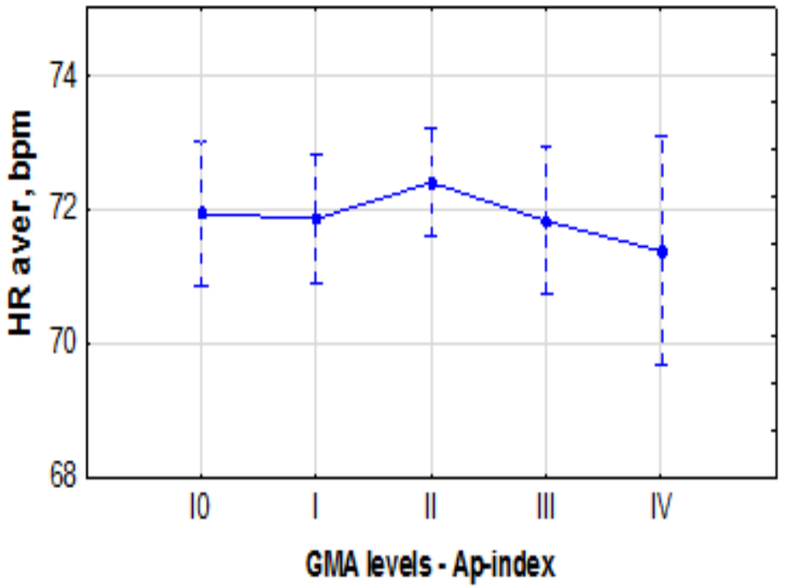
**** Statistical significant results***

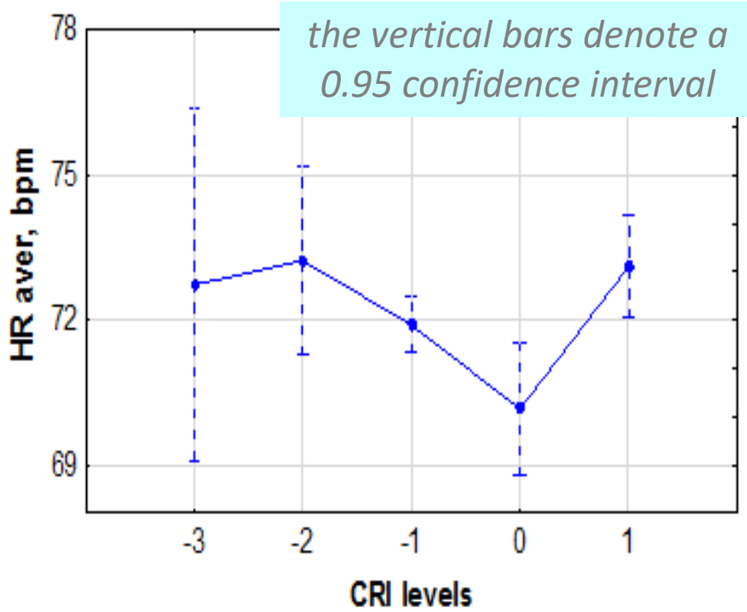
Significance levels (p - values) of GMA and CRI potential effect on HR on the days before (-), during (0) and after (+) GMA and CRI variations

3. Results

Results concerning different levels of geomagnetic and cosmic ray activity







the vertical bars denote a 0.95 confidence interval

- **High GMA levels (i.e. levels III and IV)**: Higher HR values
- **Low GMA levels (i.e. levels I0, I and II)**: Small or even no HR variations

(Mavromichalaki et al., 2021; Papailiou et al., 2023; 2024a)

- **Level II (moderate geomagnetic storms):** HR maximum
- A decrease is observed from level II and there on until level IV, when HR minimum is recorded

(Papailiou et al., 2024b)

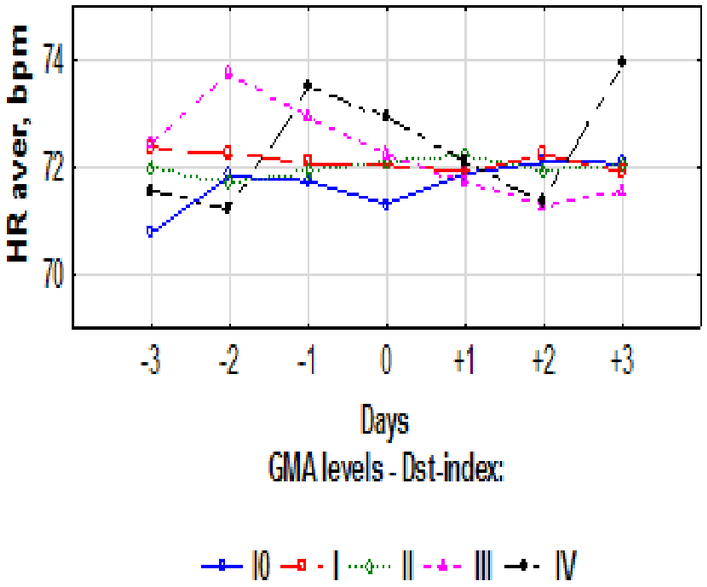
- **Severe and major CRI decreases (levels -3 and -2)**: High HR values
- **Level -3 to level 0**: HR's behavior consistent with previous results
- **Level 1**: Notable HR increase to values comparable to the ones of severe and major CRI decreases

Dst-index, Ap-index and CRI results are expected and in accordance to previous conclusions

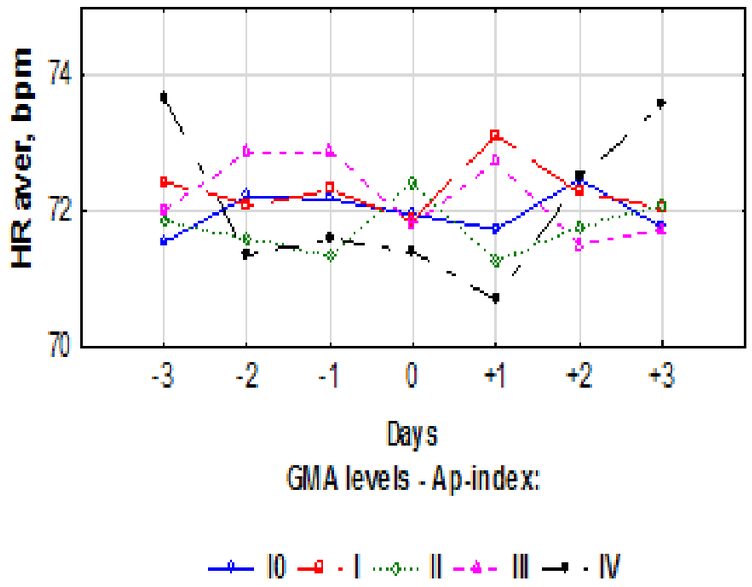
(Dimitrova et al., 2009)

3. Results

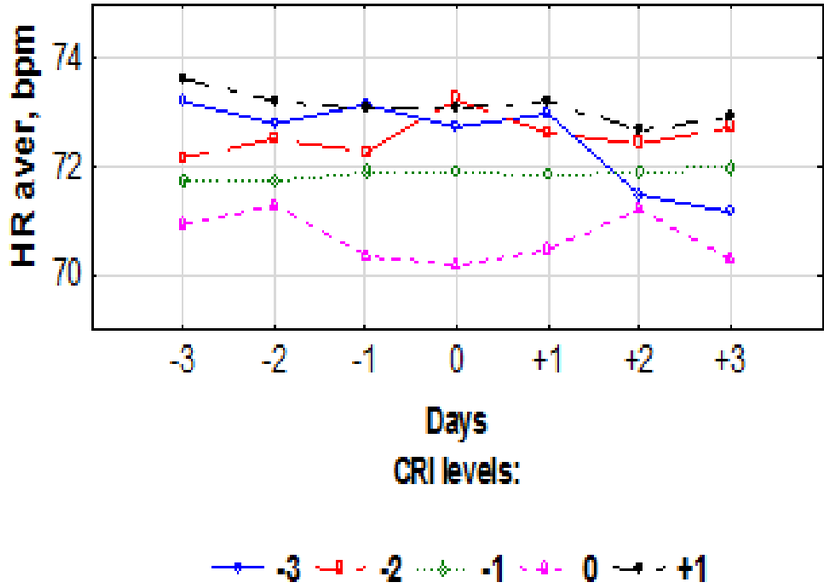
Results during the development of a physical event, i.e. geomagnetic storm and CRI variations



- **Low levels of GMA (i.e. levels I0, I and II)**: No significant variations
- **High levels of GMA (i.e. levels III and IV)**: HR had peak values for the days before and after the day of the event (Dimitrova et al., 2009; Papailiou et al., 2024a).
- HR increased on the days before the event; decreased during the event and until 2 days after the event and increased again on day +3rd.



All levels of GMA present HR variations and peak values before or after a geomagnetic storm



- **Levels -1 and +1**: No significant variations
- **High levels -3 and -2**: HR had peak values on the days before and after the day of the event
- **Level 0 (no CRI variations):** *"Minor or even no variations in the physical environment can have an impact on human physiological parameters"* (Palmer et al., 2006; Stoupel et al., 2007).

4. Conclusions

1) Concerning the **p – values**, statistical significant results were acquired:
- For the **geomagnetic Ap-index** one day after the development of physical events
- **For CRI** on days before, during and after the development of physical events
- For the **geomagnetic Dst-inde**x no statistically significant results were obtained for the days under study

2) Concerning the **different levels of geomagnetic and cosmic rays' activity** it was concluded that:
- For the **geomagnetic Dst-index**, strong and severe geomagnetic storms (levels III and IV respectively) were connected to HR increase
- For the **geomagnetic Ap-index**, high GMA levels (levels III and IV) were connected to low HR values
- For the **CRI levels**, severe and major CRI decreases (levels -3 and -2) are related to high HR values

3) **During the development of a physical event**, i.e. three days before (days -3rd, -2nd and -1st), the day during (day 0) and three days after (days +1st, +2nd and +3rd) geomagnetic storms and CRI variations it was concluded that:
- For the **geomagnetic Dst-index**, for low levels of GMA no significant HR variations were noticed. For levels III and IV, HR had peak values on the days before and after the day of the event.
- For the **geomagnetic Ap-index**, all levels of GMA present HR variations and peak values before or after a geomagnetic storm.
- For **CRI**, levels -1 and +1 showed no significant variations. For the highest levels -3 and -2 of the cosmic rays activity, HR had peak values on the days before and after the day of the event. For level 0 (no CRI variations) HR's behavior is also noticeable.

The most significant HR variations for high levels of geophysical activity were noticed mainly for the time period from 2 days before until 2 days after the events under consideration. This last observation is confirmed by various studies that state that numerous physiological parameters react to physical activity in the time vicinity of ~2 days around the physical events onset

(Azcárate et al., 2012; Vencloviene et al., 2021)

5. References

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Thank you