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A retrospective analysis of PubMed publications regarding the relationship between stress and athletes
O analiză retrospectivă a publicaţiilor PubMed pentru relaţia dintre stres şi sportivi

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Abstract

Background. Stress (S) and athletes (A) are subjects of research interest, but the S+A relationship has been little investigated.

Aims. The aim of the present paper is the evaluation of research regarding the S+A relationship, by the retrospective analysis of PubMed publications over the past 62 years.

Methods. The S+A relationship was analyzed in two types of investigations: A) Analysis of the keyword combination "stress and athletes" by the evaluation of three filters, each with corresponding sub-filters: Text availability, Species and Sex. B) Comparative analysis for the keyword combinations: "stress and athletes" (S+A), "stress and athletes and cortisol" (S+A+C), "stress and athletes and pain" (S+A+P), "stress and athletes and pain test" (S+A+PT) and "stress and athletes and VAS" (S+A+VAS).

Results. There are significant differences between the averages per year over 62 years: a) for the total number of publications (N), those with abstract (A) and full-text (FT) respectively, compared to those with free full-text (FFT); b) between studies with human subjects and those with animal subjects; c) between S+A and the other chosen keyword combinations, S+A+C, S+A+P, S+A+PT, S+A+VAS.

Conclusions. 1) The total number of publications over 62 years, with the keywords "stress and athletes", is representative, 2448. 2) For the S+A keyword combination, the number of FFT publications is low compared to N and A, which could be an impediment for detailed consultation by those with modest financial possibilities. 3) For studies with S+A keywords, human subjects of both genders were preferred. 4) The publications regarding the evaluation of stress in athletes (through cortisol) and of pain under stress conditions in athletes (through various tests, in particular VAS), although numerically modestly represented compared to the total number of publications relating to stress and athletes, are important, through the role attributed to these parameters.

Key words: stress, athletes, cortisol, pain, VAS, PubMed filters.

Rezumat

Premize. Stresul (S) şi sportivii (A) reprezintă subiecte de cercetare de interes, dar relaţia dintre cele doua teme este încă modest investigată.

Obiective. Scopul lucrării prezente îl constituie evaluarea preocupărilor de cercetare pentru relaţia S+A, prin analiza retrospectivă a publicaţiilor PubMed din ultimii 62 de ani.

Metode. Relaţia S+A a fost analizată pe doua categorii de investigaţii. A) Analiza pentru combinaţia de cuvinte cheie "stres şi sportivi", fiind evaluate trei filtre, fiecare cu subfiltrele corespunzătoare: Disponibilitatea de text, Specie şi Gen. B) Analiza comparativă pentru combinaţiile de cuvinte cheie "stres şi sportivi" (S+A), "stres şi sportivi şi cortisol" (S+A+C), "stres şi sportivi şi durere" (S+A+P), "stres şi sportivi şi test de durere" (S+A+PT), "stres şi sportivi şi VAS" (S+A+VAS).

Rezultate. Există diferenţe semnificative între mediile/an pe 62 ani: a) pentru numărul total de publicaţii (N), respectiv de abstracte (A) şi de text integral (FT), comparativ cu cel cu text integral gratuit (FFT); b) între studiile cu subiecţi umani şi cele pe animale; c) între S+A şi celelalte combinaţii de cuvinte cheie alese, S+A+C, S+A+P, S+A+PT, S+A+VAS.

Concluzii. 1) Numărul total de publicaţii pe 62 de ani, având cuvintele cheie „stres şi sportivi", este reprezentativ, 2448. 2) În cazul combinaţiei de cuvinte cheie S+A, numărul de publicaţii cu FFT este redus comparativ cu N şi cu cele cu A, ceea ce ar putea fi un impediment pentru consultarea detaliilor de către cei cu posibilităţi financiare modeste. 3) Pentru studiile având ca şi cuvinte cheie S+A, au fost preferaţi subiecţii umani, de ambele genuri. 4) Elementele de evaluare a stresului la sportivi (prin cortizol), şi a durerii în condiţii de stres la sportivi (prin diferite teste, în special prin VAS), deşi modest reprezentate numeric, faţă de totalul publicaţiilor referitoare la stres şi sportivi, sunt importante prin rolul acordat acestor parametri.

Cuvinte cheie: stres, sportivi, cortizol, durere, VAS, filtre PubMed.

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Introduction

The hypothalamic-pituitary-adrenal axis (HPA) is influenced by psychological and physical stress, depending on the type, intensity, and duration of the stressor and on the individual characteristics of the subjects (Di Luigi et al., 2008). HPA and the autonomous nervous system are activated in response to stressful stimuli (Singh et al., 1999). A number of studies in athletes have found a direct relationship between physical training and psychological stress and athletic performance (Talbott et al., 2013). However, excessive or inadequate basal activity and responsiveness of this system might impair development, growth and body composition, and lead to a host of behavioral and somatic pathological conditions (Chrousos, 2009).

Hypothesis

Exercise can be a stress factor, but at the same time it may be associated with pain, through the inflammatory implications that it can trigger. Athletes are often confronted with stress and physical pain in sport activity. However, the target relationship between stress, athletes and pain has been little investigated so far.

Objectives

The aim of the present work is the evaluation of research concerning the relationship between stress and athletes through the retrospective analysis of PubMed publications over the past 62 years.

Material and methods

The ”stress and athletes” (S+A) relationship was analyzed in two types of investigations:

A) Analysis for the S+A keyword combination, by the evaluation of three filters. Within each selected check filter, some sub-filters were analyzed, namely:

1. For the group filter *Text availability*, the chosen sub-filters were: total number of publications (T), number of publications with abstracts (A), number of publications with full text (FT) and free full text (FFT).

2. For the group filter *Species*, the chosen sub-filters were: animals (AN) and humans (H).

3. For the group filter *Sex*, the chosen sub-filters were: male (M), female (F), male and female (MF).

B) Analyses for specific keyword combinations ”stress and athletes” (S+A), ”stress and cortisol and athletes” (S+A+C), ”stress and athletes and pain” (S+A+P), ”stress and athletes and pain test” (S+A+PT), ”stress and athletes and VAS” (S+A+VAS). VAS is any analogous scale for pain. Cortisol is an important marker of stress, and VAS assessment is a commonly used test in pain assessment.

For both categories of investigation, evaluation over 62 years, the period 1950-2012, had the following elements of analysis:

a) the mean number of publications per annum, for decades 1950-59, 1960-69, 1970-79, 1980-82, 1990-99, 2000-2009; and the number of publications per year for the years 2010, 2011 and 2012;

b) the percentage of the total number of publications, for sub-filters and keyword combinations, for the whole period 1950-2012, but also for the decades and years taken into consideration.

Statistical evaluation

The results obtained were analyzed using the SPSS 13.0. statistical package. For continuous data examination, Student’s t test was used. The differences were considered significant at $p<0.05$.

Results

The data collection took place in May 2013. For all groups, data distribution was normal, according to the Kolmogorov-Smirnov test. The analysis was made for the chosen time periods.

A) Analysis for the „stress and athletes” keyword combination

1. Analysis of the *Text availability* filter

The total number of publications over 62 years (Table I) was 2448 (N), followed by A (2349), representing 96% of N, while FFT only represented 14.1% of N.

Table I
Total number of publications and percentage of N for the *Text availability* filter.

Analysis	N	A	FT	FFT
1950-2012	2448	2349	1935	347
Percentage of N	100	96	80	14.1

Significant differences were noted for the averages/year (Table II) between: FFT N-FFT (p=0.024), A-FFT (p=0.026), FT-FFT (p=0.036). The dynamic analysis of the mean number of publications over 62 years shows that N, A, FT and FFT began to increase continuously starting with 1980-89, and the maximum was reached in the year 2012: 259, 247, 241 and 61, respectively. Compared to N, A and FT, the number of FFT publications was reduced during the entire analyzed period.

Table II
Averages/year for the *Text availability* filter. Comparison of FFT.

Time period	N	A	FT	FFT
1950-1959	0.3	0	0.2	0.2
1960-1969	0.9	0.1	0.2	0.2
1970-1979	5	3	1.9	0.5
1980-1989	23.6	21.4	9.7	1.4
1990-1999	52.4	51.7	33.5	4.1
2000-2009	104.8	102.6	93.9	16.1
2010	199	198	187	34
2011	199	195	191	61
2012	**259**	**247**	**242**	**61**
Mean	93.8	91	84.4	19.8
Standard deviation	101	98.4	97.5	25.8
P-value	0.024	0.026	0.036	

The analysis of the percentage of N (Table III) for sub-filters shows that in 2010, the highest percentage was recorded for A (99.4%), and the lowest percentage for FFT (9.8%). Although the average number of A, FT and FFT publications/year was the largest in 2012, the percentage of N was significantly lower in 2012 compared to 2011, for all three sub-filters.

Table III
Percentage of N for the sub-filters of the *Text availability* filter.

Time period	N	A	FT	FFT
1950-2009	100	95.6	71.5	12
2010	100	**99.4**	93.9	*9.8*
2011	100	98	96	31
2012	100	96	93.1	23.1

2. Analysis of the *Species* filter

The total number of publications over 62 years (Table IV) in which the An sub-filter was mentioned was 136, while the H sub-filter was mentioned in 2250 publications, representing 91.9% of N.

Table IV
Total number of publications and percentage of N for the *Species* filter.

Analysis	N	An	H
1950-2012	2448	136	2250
Percentage of N	100	5.55	91.9

Significant differences were noted for the averages/year (Table V) between H-An (p=0.008). The dynamic analysis of the mean number of publications over 62 years shows that H began to increase continuously starting with 1970-79, and the maximum was reached in 2012 (208). Compared to N and H, An was reduced during the entire analyzed period.

Table V
Averages/year for the *Species* filter. Comparison of H.

Time period	N	An	H
1950-1959	0.3	0	0
1960-1969	0.9	0.7	0
1970-1979	5	0	0.5
1980-1989	23.6	1	23.4
1990-1999	52.4	3.1	48.9
2000-2009	104.8	6.9	97.6
2010	199	**11**	181
2011	199	9	180
2012	**259**	10	**208**
Mean	93.8	4.63	82.2
Standard deviation	101	4.58	86.7
P-value	0.39	0.008	

The analysis of the percentage of N (Table VI) for sub-filters shows that both for An and H, the highest percentage was recorded in the period 1950-2009 (An, 6.24; H, 91.2%), and the lowest percentage, in 2012 (An, 3.9; H, 80). Although the average number of publications/year with H was the highest in 2012, the % of N was the lowest (80%) compared to the previous periods. The % of H was higher than that of An, for all periods.

Table VI
Percentage of N for the sub-filters of the *Species* filter.

Time period	N	An	H
1950-2009	100	**6.24**	**91.2**
2010	100	5.52	91
2011	100	4.6	90.4
2012	100	*3.9*	*80*

3. Analysis of the *Sex* filter

The total number of publications over 62 years (Table VII) with most mentions was for both sub-filters, MF (1619), representing 66% of N, followed by the value of M (1374), 56.1% of N, and of F (978), 39.9% of N.

Table VII
Total number of publications and percentage of N for the *Sex* filter.

Analysis	N	M	F	MF
1950-2012	2448	1374	978	1619
Percentage of N	100	56.1	39.9	66

Non-significant differences were noted for the averages/year (Table VIII) between MF-N, MF-M, MF-F. The dynamic analysis of the mean number of publications over 62 years shows that M, F and M began to increase continuously starting with 1960-69, and the maximum values were reached in 2012: 141 (M), 84 (F), 157 (MF). Compared to M and MF, F was reduced during the entire analyzed period.

Table VIII
Averages/year for the *Sex* filter. Comparison of MF.

Time period	N	M	F	MF
1950-1959	0.3	0	0	0
1960-1969	0.9	0.5	0.1	0.5
1970-1979	5	2.1	1.4	2.6
1980-1989	23.6	14.8	11.8	17.2
1990-1999	52.4	22.7	22.4	34.3
2000-2009	104.8	59.2	41.9	70.2
2010	199	123	78	138
2011	199	125	69	139
2012	**259**	**141**	**84**	**157**
Mean	93.8	54.3	34.4	62.1
Standard deviation	101	59.6	34.9	
P-value	0.22	0.39	0.13	

The analysis of the percentage of N (Table IX) for sub-filters shows that the highest percentages were recorded in 2011 for M (62.8%), and for MF (69.8%), and in the period 1950-2009 for F (41.5%). Although the number of average F publications/year was the largest in 2012, the percentage of N was the lowest (32.4%) in 2012, compared to the other periods. MF percentages were higher than M and F percentages, for all periods.

Table IX
Percentage of N, for the sub-filters of the *Sex* filter.

Time period	N	M	F	MF
1950-2009	100	53.1	**41.5**	66.7
2010	100	61.8	39.1	69.3
2011	100	**62.8**	34.6	**69.8**
2012	100	54.4	*32.4*	60.6

B) Comparative analysis for the keyword combinations ”stress and athletes”, ”stress and athletes and cortisol”, ”stress and athletes and pain”, ”stress and athletes and pain test”, ”stress and athletes and VAS”.

The total number of publications over 62 years (Table X), for S+A+P (381), representing 15.6% of S+A, was greater than for: S+A+C (147), 6% of S+A; S+A+PT (54), 2.1% of S+A; and S+A+VAS (3), 0.12% of S+A.

Table X
Total number of publications and percentage of N for the chosen keyword combinations.

Analysis	S+A = N	S+A+C	S+A+P	S+A+PT	S+A+VAS
1950-2012	2448	147	381	54	3
Percentage of N	100	6	15.6	2.1	0.12

Differences were noted for the averages/year between S+A and the other chosen keyword combinations (Table XI): S+A+P, moderately significant (0.015); S+A+C (0.0099), S+A+PT (0.007) and S+A+VAS (0.0067), highly significant. The dynamic analysis of the mean number of publications over 62 years shows that for S+A (259) and S+A+P (37), the maximum values were reached in 2012; for S+A+C (17) in 2011, and for S+A+PT (5) and S+A+VAS (2), in 2010. Compared to the other chosen keyword combinations, S+A+VAS values were reduced during the entire analyzed period, and in the period 1950-2009 and in 2012 they were equal to zero.

Table XI
Averages/year for the chosen keyword combinations. Comparison of S+A.

Time period	S+A	S+A+C	S+A+P	S+A+PT	S+A+VAS
1950-1959	0.3	0	0	0	0
1960-1969	0.9	0	0.1	0	0
1970-1979	5	0.1	0.8	0.1	0
1980-1989	23.6	0.9	4.2	0.6	0
1990-1999	52.4	3.3	8.3	0.7	0
2000-2009	104.8	6.5	17.1	2.8	0
2010	199	16	25	**5**	**2**
2011	199	**17**	22	2	1
2012	**259**	15	**37**	3	0
Mean	93.8	6.53	12.7	1.58	0.33
Standard deviation	101	7.41	13.2	1.74	0.71
P-value		0.0099	0.015	0.007	0.0067

The analysis of the percentage of S+A (=N) (Table XII) for sub-filters shows that the highest percentages were recorded: in 2011 for S+A+C (8.9%), in the period 1950-2009 for S+A+P (16.3), and in 2010 for S+A+PT (2.51%) and S+A+VAS (1%). Although the average number of publications/year with S+A+P was the highest in 2012, the % of S+A was low (14.3%) compared to other periods. S+A+C had in 2012 the lowest percentage of S+A compared to the previous periods. S+A+P percentages were higher than S+A+C, S+A+PT, S+A+VAS percentages, for all periods.

Table XII
Percentage of S+A for the chosen keyword combinations.

Time period	S+A	S+A+C	S+A+P	S+A+PT	S+A+VAS
1950-2009	100	6	**16.3**	2.24	0
2010	100	8	12.5	**2.51**	**1**
2011	100	**8.9**	11	1	0.5
2012	100	*5.9*	14.3	1.14	0

Discussion

The *Text availability* group filter. The rationale for the choice of T, A, FT, FFT sub-filters is that the information choosing steps start from the title of the publication, continue with the reading of the summary, and then, depending on interest, with the full text. Free full-text publications are a real help.

The *Species* group filter. The rationale for An and H sub-filters starts from the idea that the studies that refer to polyphenols and sports are both clinical and experimental. The choice of one or other of these sub-filters is useful in selecting studies.

The *Sex* group filter. The rationale for M, F, MF sub-filters is based on the fact that there may be differences in results between genders, for studies with the ”stress + athletes” topic. Some of these studies include in the analyzed groups only one gender, other studies, both of them.

The dynamic evolution of N, A, FT and FFT proves that between 1950-1979, so for a 30 year period, the number of studies including these sub-filters for the ”sports and athletes” keywords was reduced. Between 1950-59, no A was recorded. The interest in this topic began to grow starting with 1980, the average number of publications per annum being the largest in 2012. Of these publications, the number of FFT was constantly diminished compared to N and FT, the differences of these sub-filters being significant. Thus, the difficulty in having full information access to these publications without FFT can be noticed.

The dynamic evolution of An and H shows that between 1950-1979, so for a 30 year period, the number of studies including these sub-filters for the ”sports and athletes” keywords were reduced. For An, there was no mention between 1950-59, 1970-79, and for H, there was no mention between 1950-69. The interest in these sub-filters began to grow in the 1980s, the average number of publications per annum being the highest in 2010 for An, and in 2012 for H. The significant difference between H and An (p=0.008) shows a tendency towards research on human subjects.

The dynamic evolution of M, F and MF shows that between 1950-1979, so for a 30 year period, the number of studies including these sub-filters for the ”sports and athletes” keywords was reduced. For M, F and MF, there was no mention between 1950-59. The interest in these sub-filters began to grow in the 1980s, the average number of publications per annum being the highest in 2012 for M, F and MF. Although MF values were permanently higher compared to M and F values, the differences were not significant. We notice that in the case of studies with the ”sport and athletes” keywords, M and MF subjects were preferred.

Comparative analysis for the keyword combination ”stress and athletes”, ”stress and athletes and cortisol”, ”stress and athletes and pain”, ”stress and athletes and pain test”, ”stress and athletes and VAS”.

The dynamic evolution of M, F and MF shows that between 1950-1979, so for a 30 year period, the number of studies including these sub-filters for the „sports and athletes” keywords was reduced. There was no mention: for S+A+C, between 1950-69; for S+A+P, between 1950-59; for S+A+PT, between 1950-69; for S+A+VAS, between 1950-2009 and in 2012. The interest in S+A+C, S+A+P, S+A+PT began to grow in the 1980s. The average number of publications per annum was the largest in 2010, for S+A+VAS; in 2011, for S+A+C; and in 2012, for

S+A+P and S+A+PT. Differences between S+A and the other chosen keyword combinations were significant.

Cortisol is an important biological marker of stress. We quote some important references below:

"The stress response is mediated by the stress system, partly located in the central nervous system and partly in peripheral organs" (Chrousos, 2009). "During stress events, neurons of paraventricular nuclei rapidly secrete CRH that activate HPA axis by stimulating ACTH secretion, that in turn stimulates cortisol output" (Di Luigi et al., 2008).

"Many published reviews describe the role of cortisol in health and disease and the use of different cortisol measures in stress research" (Chrousos, 2009; Gow et al., 2010; McEwen, 1998; Russell, 2012; Stalder and Kirschbaum, 2012, Gerber et al., 2012). "Normal healthy men exhibited an exaggerated neuroendocrine response to high intensity exercise, responders showed significantly greater ACTH, cortisol, and arginine vasopressin (AVP) responses to exercise" (Singh et al., 1999).

"Sustained exercise, even in a thermally comfortable environment, induces a larger hormonal response than moderate thermal stress" (Brenner et al., 1998). "Intense or prolonged exercise and/or heat stress might affect the immune system creating a response similar to trauma or inflammation; during prolonged exercise, inflammatory cytokines, and the stress hormone cortisol are produced and released" (Cosio-Lima, 2012). "Exercise intensity and exposure to heat are correlated to the release of plasma cortisol levels in athletes, astfel, total cortisol concentrations were significantly elevated ($p<0.05$) immediately post-exercise, and from pre- to 12 hours post-exercise" (Cosio-Lima, 2012). "Very hot conditions induce a typical stress response, with secretion of catecholamines and cortisol, that subsequently causes cells to migrate to lymphoid tissue; as exercise continues, plasma cortisol levels also rise, inducing an influx of neutrophils from bone marrow and an efflux of other leukocyte subsets" (Brenner et al., 1998). "Athletes who experience repeated exposure to high heat and humidity during the summer months while in the competitive season can suffer chronic inflammation" (Cosio-Lima, 2012).

"In exercise and sport science, hair cortisol could be used by researchers interested in stress fractures" (Fredericson et al., 2005, Gerber et al., 2012), injury (Albinson & Petrie, 2003, Gerber et al., 2012), sources of organizational stress (Fletcher & Hanton, 2003, Gerber et al., 2012), competitive stress (Mellalieu et al., 2009, Gerber et al., 2012), or the "interplay between stress, recovery, overtraining and burnout among elite athletes" (Kellmann, 2010, Gerber et al., 2012).

However, in the case of investigations targeting both stress and athletes, only 6% of them were related to cortisol.

Pain is a symptom commonly encountered in the field of sports. The association between stress, athletes and pain has been little explored. We quote some important references below:

"Stress fractures are common injuries in athletes and military recruits that occur more commonly in lower extremities than in upper extremities; these stress fractures should be considered in patients who present with tenderness or edema after a recent increase in activity or repeated activity with limited rest" (Patel et al., 2011). "Stress fractures have been reported at the acromion in a football lineman, golfer, and elite tennis player; water polo too is an intense sport with extreme physical contact and repetitive shoulder motion that predisposes to injury" (Donaldson, 2012). "Benign neck pain is common in athletes and is usually the result of minor sprains, strains, or contusions; athletes with neck pain may have deficits in cervical and/or upper thoracic mobility, muscle recruitment, strength and endurance, repositioning acuity, postural stability, and oculomotor control" (Durall, 2012). "Groin pain in athletes is one of the most difficult to treat clinical entities in sports medicine" (Weber et al., 2013).

However, only 15.6% of S + A studies were related to pain.

For the *assessment of pain*, including in sport, different tests are used, VAS being a common one. We quote some important references below:

"Chronic lower extremity pain in athletes includes a wide differential and can pose diagnostic dilemmas for clinicians" (Brewer & Gregory, 2012). The *VAS scale* was used to assess pain in athletes, in a few studies with: traumatic knee dislocation (Hirschmann et al., 2010), alteration in scapular motion and shoulder pain (Merolla et al., 2010), chronic ankle instability (Lee et al., 2011).

The keyword combinations used show that only 2.1% of S+A studies dealt with pain tests (S+S+PT), while VAS (S+A+VAS) was a concern of only 0.21% of S+A, totaling a number of 3 publications in 62 years.

It is noteworthy that the number of publications, smaller or larger with respect to a sub-filter or a keyword combination, is not necessarily reflected by the proportion that they represent of the total number of publications to which reference is made. For example, although the number of H publications was the highest in 2012, their % of N was the lowest compared to the previous periods. These discrepancies could be explained by the proportion variability of a particular sub-filter or keyword combination in the published studies.

Conclusions

1. The total number of publications over a 62-year period, with the „stress and athletes" keywords, is representative, 2448.
2. For the S+A keyword combination, the number of FFT publications is low compared to N and A, which could be an impediment for detailed consultation by those with modest financial possibilities.
3. For studies with the S+A keywords, human subjects of both genders are preferred.
4. The publications regarding the evaluation of stress in athletes (through cortisol) and of pain under stress conditions in athletes (through various tests, in particular VAS), although numerically modestly represented compared to the total number of publications relating to stress and athletes, are important, through the role attributed to these parameters.

Conflicts of interest

Nothing to declare.

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