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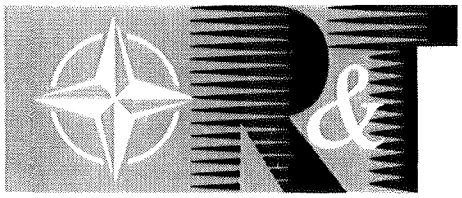

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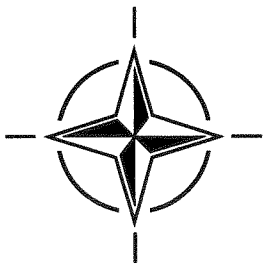
RTO MEETING PROCEEDINGS 33

Operational Issues of Aging Crewmembers

(les Conséquences opérationnelles du vieillissement des équipages)

Papers presented at the RTO Human Factors and Medicine Panel (HFM) Symposium, held in Toulon, France, 11-14 October 1999.



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AGE EFFECT ON AUTONOMIC CARDIOVASCULAR CONTROL IN PILOTS

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ABSTRACT

The autonomic cardiovascular control was determined as a function of age in 66 military pilots and in 39 referents, both groups aged from 20 to 55 yr. It was assessed by time-domain and frequency-domain heart rate variability (HRV) measures and with some HRV-derived indices. Most sensitive to aging process from time-domain HRV measures revealed to be short-term variability and time-domain index, and from frequency-domain HRV measures frequency-domain index. The activity of both ANS branches was found to decline with age, but a different extent of decrease of sympathetic as compared to parasympathetic activity was observed: sympathetic activity reflected by the spectral power of the R-R intervals in the temperature - mediated spectral frequency band (0.01-0.05 Hz) decline more slowly than parasympathetic activity reflected by respiratory sinus arrhythmia - mediated spectral frequency band (0.15-0.50 Hz). As well as such age-desynchronized autonomic cardiovascular control was found only in military pilots but not in referents it is concluded that the aging process in pilots is accelerated due to repetitive and prolonged exposure to persisting stress, caused by the compulsory underload (substantial reduction of flying tasks and physical exercises coinciding with personal interviews). Although the computed Overall Health Risk values in both groups were not substantially deviated from "normal", those in military pilots was significantly higher.

INTRODUCTION

Aging process is accompanied with regular changes in the repair and maintenance of most physiological functions. Functional response integrity and its adaptive capacity are affected by age. During aging process physiological functions perturb different extent of changes.
Age-associated neural, receptor and end-organ changes modify integration and regulation of cardiovascular responses. Mechanisms governing cardiovascular regulation, involve in part autonomic influences.

Considerable interest exists on the effects of age on the Autonomic Nervous System (ANS) that raises the question how to measure autonomic function quantitatively. Heart rate fluctuations are result of reciprocal control of the sympathetic and parasympathetic activities. As normal variations in resting heart rate are due to the tonic changing levels of activity of both ANS divisions, Heart Rate Variability (HRV) has been the focus of previous and recent studies on the effect of age on the ANS. HRV is a noninvasive method for assessment of autonomic nerve activity. Three components of HRV are involved in the autonomic control of heart rate fluctuations:

HRV Components

1. Temperature component of heart rate fluctuations in the frequency band: 0.01 - 0.05 Hz, related to thermoregulatory and peripheral vascular mechanisms, mediated by sympathetic activity (2; 26).

2. Traube-Hering-Mayer wave component of heart rate fluctuations in the frequency band: 0.06 - 0.14 Hz, reflected short-term blood pressure regulation, jointly mediated by sympathetic and parasympathetic activities (2; 35; 45).

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diminished vagal activity accompanying aging (25; 36). Strong evidence for declining of parasympathetic activity is the change of RSA component of HRV. An inverse linear relationship between the RSA amplitude and age (21-54 yr) has been found (18) but no further decrease in RSA has been observed after age 50 yr in normal subjects (59). The inverse relationship of RSA and age has been confirmed, where RSA amplitude rapidly decreases from 20 to 35 yr and then shows no further decrease up to 78 yr (19). The RSA amplitude falls approximately 10 percent per decade (20). Pronounced reduction of respiratory related heart rate oscillations in the frequency range (0.15-0.40 Hz) compared with preserved vasomotor rhythms is found (38).

Contrary to these findings other studies suggest the theses of age-associated declining or increasing of relative dominance of sympathetic activity in autonomic cardiac control. Relatively larger decline has observed in the temperature- , and the T-H-M wave HRV components (related to thermoregulatory, vasomotor and renin-angiotensin control mechanisms) compared to respiratory component (22). In contrast to the observed decline in the temperature- and the T-H-M wave HRV components, an increasing of the temperature-/the RSA ratio (spectral marker of the sympathetic activity) and the spectral power in the temperature band (currently considered sympathetically mediated) in another studies are attributed to increase in relative dominance of the sympathetic influence in autonomic cardiac control with age (8; 61; 62).

In summary it can be stated that changes of the parasympathetic and sympathetic mediation of heart rate are important determinants of age dependence of HRV and are involved in the age genesis of the HRV components. Aging may cause opposite effects on the autonomic functioning: reduction of both sympathetic and parasympathetic tone; pronounced attenuation of the predominance of the parasympathetic activity and/or declining, resp. increasing of the relative dominance of the sympathetic activity. These data indicate that the problem of whether both sympathetic and parasympathetic tone is changed to the same extent with age is controversial.

Examination of the age-associated ANS functioning will contribute to the clarifying of the effect of aging on sympathetic and parasympathetic branches of the ANS in military pilots.

The aim of the present study was to determine the functional role of the autonomic cardiovascular control as a function of age in military pilots.

Determination of age-modified autonomic control in military pilots would help to understand whether stressful work environment would alter the pattern of normal aging process.

This study will test the hypothesis that the functional role of the autonomic cardiovascular control is changed as a function of age. The proposition inherent in this hypothesis is that a cause-effect relationship exists between age-modified autonomic control and cardiovascular function.

METHODS

Subjects

Two groups of subjects participated in this study: military pilots and referents (employees). First group consisted of 66 male military pilots employed by the Bulgarian Military Air Force and students of the Bulgarian Military Air Academy whose ages ranged from 20 to 55 years (mean age X±SD 34.85±10.71). Referent group consisted of 39 male subjects who were employees in institutions matched for age (X±SD 34.13±11.00; age range: 20 to 55 yr) to the military pilots.

Criteria for exclusion included: systolic blood pressure>130 mmHg; diastolic blood pressure>85 mmHg; body-mass index>25 $kg/m^{2;}$ smoking; using medications; diabetes; cholesterolaemia; and a history or evidence of cardiovascular, respiratory, renal, hepatic, gastrointestinal or systemic disease.

Procedure

HRV data were determined from 10 min ECG recordings between 9 a.m. and 11 a.m. in supine position after 1 h rest period. HRV data were obtained in three consecutive days and mean individual values from the measurements were calculated.

Heart Rate Variability

Computerized method for analyzing of HRV was applied (12). An ECG was registered from a bipolar standard Ist lead.

A portable electronic device was used to transform ECG signal into R-R intervals and to emit (transmit) R-R intervals to IBM compatible PC for on-line processing. ECG signal is transformed to R-R intervals by AC converter (QRS detector and timer, resolution time 2224 samples per second). This sampling rate gives a variation of 0.48 msec in locating the peak of R-wave and results in a minimum accuracy of 99.55 % in computing heart rate up to 140 beats/min.

Time-domain and frequency-domain HRV measures, and HRV derived indices were analyzed:

Fig. 1. Mean values of the $P_T(ms^2)$ and $P_{RSA}(ms^2)$ in referent and military pilots groups.

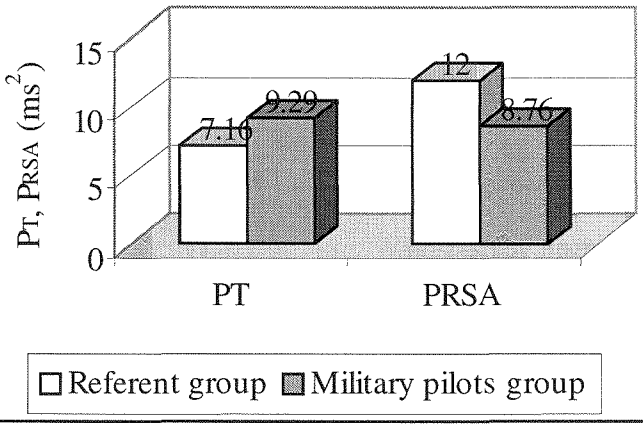


Fig. 2. Mean values of the MS (arb.un.) in referent (I) and military pilots (II) groups.

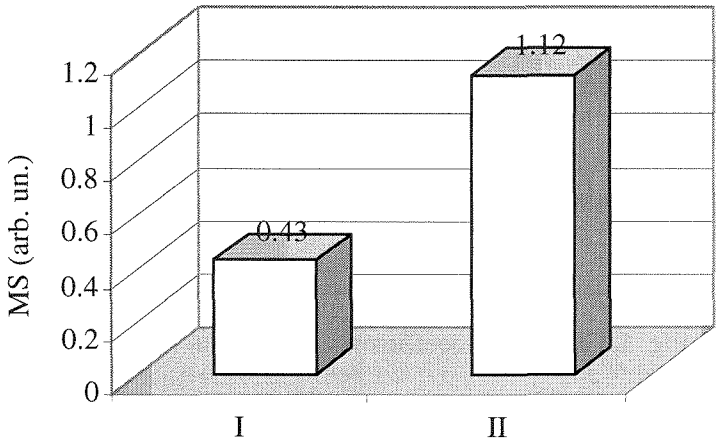
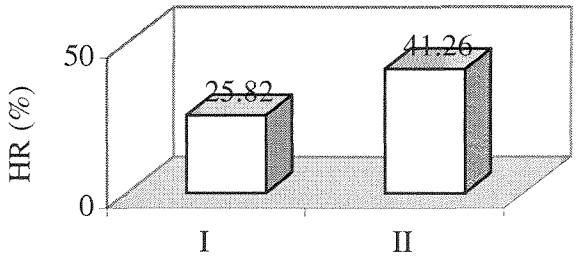


Fig. 3. Mean values of the HR (%) in referent (I) and military pilots (II) groups.



2. Age Dependencies of HRV

Autonomic cardiovascular control assessed by HRV declines progressively as a function of age in pilots. This pattern was observed for both time- and frequency-domain HRV measures.

- Time-domain HRV measures: STV and TDI decreased markedly with age while (whereas) LTV decreased more gradually with age. Regression coefficients are presented in table 2.
- Frequency-domain HRV measures: Differentiated spectral powers of R-R intervals in the respective frequency bands declined slowly with advancing age compared with time-domain HRV measures. Slowest extent of age decline showed P_T. Contrary to the slow decline of P_T, P_{THM} and P_{RSA}, FDI (P_T/P_{RSA}) demonstrated rapid decline with aging. Regression coefficients are presented in table 2.
- HRV-derived indices: In contrast to HRV measures MS, HR and FA increased progressively with advanced age. Regression coefficients are presented in table 2.

Table 2. Significant regression coefficients of dependence of age on HRV.

Variables		Referent group	Military pilot group
Time-domain HRV measures			
	STV	-	-1.00***
	LTV	-	-0.72***
	TDI	-	-0.97***
Frequency-domain HRV measures			
	FDI	-	-0.62***
	P_T	-	-0.09***
	P_{THM}	-	-0.20***
	P_{RSA}	-	-0.21***
HRV-derived indices			
	PS	-0.04***	0.04***
	MS	-0.03***	1.01***
	HR	-	1.15***
	FA	0.77***	1.01***
X (mean R-R)		-	-
Heart rate		-	-

***p<0.0005

In referents significant regression coefficients of dependence of age on HRV were observed for FA, PS and MS. Regression coefficients are presented in table 2.

3. Association of Health Risk with HRV measures

Although the Health Risk (HR) values were normal among both groups, HR was significantly increased in military pilots compared with referents (table 1 and fig. 3).

Age-modified autonomic cardiovascular control in military pilots was related to health risk. Correlation of age with HR is r=0.56, p<0.0001. Significant correlations were observed between HR and time-domain HRV measures: STV (r=-0.83, p<0.0001), LTV (r=0.71, p<0.0001), TDI (r=0.86, p<0.0001); and frequency-domain HRV measures: FDI (r=0.83, p<0.0001), P_T (r=0.45, p<0.0001), P_{THM} (r=0.72, p<0.0001), P_{RSA} (r=-0.86, p<0.0001).

In referent group significant correlations of HR with HRV measures were not observed.

DISCUSSION

Autonomic cardiovascular control examined by HRV measures and HRV-derived indices changed as a function of age in military pilots. Both sympathetic and parasympathetic mediated HRV measures: time-domain measures (STV, LTV and TDI) and frequency-domain measures (P_T, P_{THM}, P_{RSA} and FDI) declined with advancing age. The most sensitive changes to aging process revealed STV (thought to reflect respiratory sinus arrhythmia) (12; 47), TDI (thought to reflect sympathetic/parasympathetic influences on histogram R-R intervals distribution) (12) and FDI (thought to represent ratio of sympathetic/parasympathetic modulation on R-R intervals) (12).

Our results revealed that both ANS divisions declined with age but we observed different extent of decreasing of sympathetic and parasympathetic determinants involved in the age genesis of HRV components. It is important to note that the observed by us dependencies of age on HRV measures (assessed by linear regression analysis) are valid only for age range 20-55 yr.

Sympathetic activity mediating P_T declined more slowly with increasing age than parasympathetic activity mediating P_{RSA}. This pattern was observed also for age-associated LTV change. Compared to STV and TDI, LTV decreased more slowly with advancing age. In contrast to parasympathetically mediated RSA explaining STV change, LTV represents baroreflex- and thermoregulatory-related HRV that are sympathetically and parasympathetically mediated. This result is consistent with finding of Korkushko et al. (27) who reported a different pattern of impairment of sympathetic and parasympathetic tone: power in high-frequency band (0.2-0.4 Hz) declines from the

4. According to the doctrine of the autonomic space of Cacioppo et all. (8) and Berntson et all. (4) the examined age-associated autonomic cardiovascular control can be defined as "coupled non-reciprocal (co-inhibition) mode of autonomic control".
5. Although the health risk values among both groups were normal, military pilots revealed higher values of health risk compared with referents.

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