Functional Effect of Stress and Optimization of Total Medical Readiness by Physical Training Program

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Abstract
Cognitive effect of peacekeeping stressors induces activation of physiological mechanisms regulating organism’s functional state. The aim of the present study was to determine the effect of peacekeeping stress on cardiac autonomic function and to establish whether physiological adaptation and medical readiness throughout peacekeeping deployment might be influenced and optimized through regular physical training. Study population included 60 male peacekeepers deployed on a peacekeeping mission (PKM) in Bosnia, Kosovo (PKM-BK), and 23 male peacekeepers deployed on a PKM in Afghanistan (PKM-A). Functional state was examined with Heart Rate Variability, intrinsic (I-hr) and actual heart rate (A-hr) at the re-deployment phase. During peacekeeping deployment in Afghanistan peacekeepers actively performed physical exercises. Peacekeeper stress was associated with a significant increase in mean A-hr, I-hr, health risk (HR), and significant decreases in mean values of mean cardiointerval, spectral powers of cardiointervals in peacekeepers participating in PKM-BK, as compared to peacekeepers participating in PKM-A. In peacekeepers participating in PKM-A no regression dependence of physical stress (PS) on mental stress or of PS on HR was found. The integrated cognitive-cardiovascular response to peacekeeping stress is more affected by peacekeeping stress in PKM-BK in comparison to PKM-A. Medical readiness may be optimized by maintenance of physical exercises during deployment phases.

1. Introduction
Psychological and social stressors, risk of terrorist and combat attacks contribute to the high degree of stress in contemporary PKM [1-5]. A basic element in peacekeeping research involves the cognitive appraisal of the nature of peacekeeping stressors and its impact on mental, affective and behavioral state. Cognitive appraisals underlie psychological resiliency and vulnerability, induced coping efforts and the intensity of stress reactions [6]. Peacekeeping stress research [4,7-10] and research of Post-Traumatic Stress Disorder (PTSD) emphasize the role of cognitive appraisal of the stressor and its
effect on health state [11-15]. Social cognitive and psychophysiological theories of stress research are directed at classifying response patterns of physiological indices under environmental cognitive intake/rejection tasks, and functional mechanisms of active/passive coping [16-18]. Data derived from application of cognitive and psychophysiological stress theories reveal decreased/increased heart rate under intake/rejection tasks, [12] and use of active coping strategies in peacekeeping deployment [19]. Results from psychophysiological studies indicate that the heart rate changes and cardiac activity measures (tonic level, phasic changes, variations in cardiac cycle) are manifestations of motor, perceptive and information processing [20]. As indices of cortical activity, they might be used in the study of cognitive processes.

Peacekeeping stressors test medical and psychological readiness, functional adaptation, and resilience of peacekeepers participating in PKM. Recent studies of the Soldier Adaptation Model and its applications to peacekeeping research provide a profound analysis of the factors that may moderate the effects of peacekeeping stress [21]. Moderators are those factors that ameliorate or attenuate the relationship between stressors and strain, and the mechanisms and coping styles that underlie soldier adaptation. Another important theory, addresses the coping strategies that are used to modify the adverse effects of the peacekeeping environment on cognitive state [19]. Of particular interest to peacekeeping psychophysiological research is physical training, one of the cognitive coping distraction strategies, which is used to reduce the effect of peacekeeping stressors [19]. Physical and mental fitness programs are suggested for improving the psychological resilience of military personnel [11, 22].

The basic principle and major objective of physical training is to facilitate physiological adaptation that improves performance in specific tasks. Aerobic fitness training is associated with adaptations in functional and dimensional cardiovascular indices. Exercise training induces an imbalance between the tonic activity of autonomic branches, reflected in greater vagal dominance. Training-induced vagal dominance decreases the intrinsic firing rate of sino-atrial (S-A) nodal pacemaker activity, which causes a decrease in intrinsic heart rate [23-25]. The decrease of intrinsic heart rate is an important sign of physiological adaptation resulting from aerobic training [26]. Physical fitness provides significant protection from cardiovascular risk factors [27] through the following mechanisms: improves myocardial circulation and metabolism; enhances the mechanical properties of the myocardium; favorably alters heart rate, blood pressure, blood-clotting characteristics, body composition, neuro-hormonal balance, and response pattern to psychological stress [28-31]. Physical training also results in psychological adaptation. It influences cognition, coping style and performance, reduces anxiety, depression and neuroticism, and improves mood, and self-esteem [32, 33]. These psychological changes may influence the cognitive appraisal of stressful situations and perception of stressors [26]. The level of arousal and psychophysiological reactivity may decrease.

The aim of the present study was to determine the effect of peacekeeping stress on cardiac autonomic function of peacekeepers participating in PKM in Bosnia, Kosovo, and Afghanistan, and to establish whether physiological adaptation and total medical readiness throughout peacekeeping deployment might be influenced and optimized through regular physical training.

2. Materials and Methods

2.1. Subjects

The study population included two groups: 60 male peacekeepers (mean age/SD, 28.35/6.73 yr) deployed on a six-month peacekeeping mission in Bosnia and Kosovo (PKM-BK), examined at the re-deployment phase; 23 male peacekeepers (28.7.3/5.83 yr) deployed on a six-month peacekeeping mission in Afghanistan (PKM-A), examined at the re-deployment phase. The individuals were examined at the Center for Military Medical Expertise, Sofia.

Peacekeepers were selected to be physically and psychologically healthy and suited for deployment according to national military medical standards [34]. Human investigations were approved by the review board of the Center for Military Medical Expertise at the Military Medical Academy. Informed consent was obtained from study participants in oral form.

To participate in PKM, militaries were selected to correspond to the following inclusion criteria: physical and psychological health status according to national military medical standards for selection and participation in PKM; deployment on a six-month peacekeeping mission; exposure to peacekeeping stress; examination at the re-deployment phase; peacekeeping deployment in Afghanistan was associated with performance of two hours per day program of physical aerobic fitness exercises. Exclusion criteria for militarys to participate in PKM were the following: Systolic blood pressure greater than 130 mmHg; Diastolic blood pressure greater than 85 mmHg; Body-Mass Index greater than 25 kg/m²; excessive use of alcohol, caffeine, and/or nicotine.

2.2. Heart Rate Variability

A computerized diagnostic system was used to examine the medical readiness of the functional state of the cardiovascular system using measures of Heart Rate Variability (HRV). The system consists of specialized hardware and software that enables the following functional tests to be performed: Cardiotachogram; Histogram; Scattergram; Power Spectrum Analysis of HRV, Mental and Physical Stress, Health Risk [35,36].

HRV data were determined from ten minutes of ECG recordings between 9 a.m. and 11 a.m. in supine position after a one-hour rest period. HRV data were obtained on three
consecutive days and mean individual values of the measurements were calculated. A portable electronic device was used to transform the ECG signal into cardiointervals (RR intervals) and to transmit the cardiointervals (RR intervals) to an IBM compatible PC for on-line processing. The ECG signal was transformed to RR intervals with an AC converter (QRS detector and timer, resolution time 2224 samples per second). This sampling rate gives a variation of 0.48 milliseconds in locating the peak of R wave and results in a minimum accuracy of 99.55% in computing heart rate up to 140 beats per minute.

Time-domain and frequency-domain based HRV measures and HRV derived indices were analyzed.

The time-domain HRV measures are associated with the time characteristics of consecutive series of RR intervals. The time-domain HRV measures include: mean cardiointerval (mean RR interval) (milliseconds), resp. mean heart rate (beats per minute).

The frequency-domain HRV measures reflect the oscillatory rhythm of the physiological control systems controlling the variations in RR intervals in the following frequency bands: 0.01-0.05 Hz; 0.06-0.14 Hz; 0.15-0.50 Hz. The spectral power of RR intervals in the respective frequency bands were calculated using Fast Fourier Transform.

The spectral power of RR intervals in the Temperature Mayer band (0.01-0.05 Hz) (THM) (milliseconds \(^2\)) reflects the fluctuations of RR intervals in association with the thermoregulatory variations of peripheral vascular resistance. The fluctuations in peripheral vascular resistance are accompanied by fluctuations with the same frequency in heart rate and are mediated by the sympathetic nervous system. The spontaneous oscillatory rhythm has a periodicity longer than 30 sec.

The spectral power of RR intervals in the Traube-Hering-Mayer band (0.06-0.14 Hz) (THM) (milliseconds \(^2\)) reflects the fluctuations of RR intervals in relation to the oscillatory rhythm of the arterial blood pressure regulatory system consisting of the afferent nerve impulsion from arterial baroreceptors, cardiovascular regulating center and the vagal and sympathetic functional activity which modulate the heart rhythm and peripheral vascular resistance. The spontaneous oscillatory rhythm in heart rate has a periodicity 10 sec (0.1 Hz) and is synchronous with the fluctuations in blood pressure: the Traube-Hering-Mayer wave. The THM is thought sympathetically and parasympathetically mediated.

The spectral power of RR intervals in the Respiratory Sinus Arrhythmia (RSA) band (0.15-0.50 Hz) (RSA) (milliseconds\(^2\)) reflects the fluctuations of RR intervals related to the inspiratory inhibition of the parasympathetic tone. The inspiratory inhibition is caused primarily by control irradiation of impulses from the medullary respiratory to the cariovascular center. The RSA is vagally mediated. The spontaneous oscillatory rhythm of heart rate fluctuations related to respiratory rate has a periodicity shorter than 10 sec.

HRV-derived indices include Physical Stress, Mental Stress, and Health Risk.

Physical Stress (PS) (arbitrary units) (mathematical algorithm based on difference between measured and age-referent values derived from time-domain HRV measures); Mental Stress (MS) (arbitrary units) (mathematical algorithm based on difference between measured and age-referent values derived from frequency-domain HRV measures); Health Risk (HR) (percentage) (mathematical algorithm derived from PS-, MS-coefficients and number of extrasystoles).

2.3. Actual and Intrinsic Heart Rate

The actual heart rate represents the mean value of heart rate and is calculated in beats per minute. The actual heart rate was derived from computer analysis of HRV. The intrinsic heart rate was calculated according to the Rosenblueth-Simeone model [37]. The Rosenblueth-Simeone model postulates that the actual heart rate value is equal to the product of the value of intrinsic heart rate, and values of the indices m, and n: Actual heart rate = m * n * Intrinsic heart rate, where m represents sympathetic acceleration and n represents vagal deceleration. In the supine position at rest conditions, values of m and n are 1.15 and 0.6. Intrinsic heart rate was calculated in beats per minute. Intrinsic heart rate was used to compare the level of peacekeeping stress in different PKM and to determine the effect of training on the firing rate of S-A nodal activity.

2.4. Personal Interviews

Personal interviews with peacekeepers were conducted to examine stressors and to elicit the types of stress. All participants have similar stressors. Scoring methods were not used.

2.5. Physical Fitness Program

During peacekeeping deployment in Afghanistan peacekeepers actively performed daily physical aerobic fitness exercises with complex loading of the body - mean exercise daily duration two hours/day. Following indoor regular fitness exercises were performed: weight lifting; body building; pushups; situps; pullups; boxing etc. Physical training program was introduced to test and assess whether the effect of physical exercises might influence the physiological adaptation and decrease the level of peacekeeping stress, stabilize psychological resilience of peacekeepers, sustain optimal functional state, maintain adequate performance to execute duties in highly risk conditions, and to determine its future role as an intervention prevention strategy for decreasing stress and reducing risk in PKM. The nature of peacekeeping mission in Afghanistan was featured with exposure to stressors non-inherent of PKM in Bosnia and Kosovo. Deployment in confined space, lack of diversity and contact with different people, living at camps induce specific psychological and social stress that might be treated with increasing level of physical activity.
2.6. Data Analyses

The following methods were employed for data analysis: independent sample t-tests of Student and Fisher; correlations and linear regression analyses. A p value <0.05 was considered statistically significant.

3. Results

Stress Differences in PKM Groups

To examine the extent of stress reaction of peacekeepers participating in different PKM (1. Bosnia and Kosovo; 2. Afghanistan), both were examined at the re-deployment phase, actual and intrinsic heart rate, and HRV indices were compared between each condition by t-test. The mean values of actual and intrinsic heart rate, and HRV indices in peacekeepers at the re-deployment phase are presented in Table I.

<table>
<thead>
<tr>
<th>Variables</th>
<th>PKM Bosnia and Kosovo,1 (n=60) X ± SD</th>
<th>PKM Afghanistan, 2 (n=23) X ± SD</th>
<th>P 1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual heart rate (beats per minute)</td>
<td>74.4 ± 9.57</td>
<td>68.6 ± 12.47</td>
<td>.02</td>
</tr>
<tr>
<td>Intrinsic heart rate (beats per minute)</td>
<td>107.9 ± 10.7</td>
<td>99.4 ± 9.6</td>
<td>.02</td>
</tr>
<tr>
<td>Mean RR interval (milliseconds)</td>
<td>795.8 ± 179.5</td>
<td>900.5 ± 152.0</td>
<td>.01</td>
</tr>
<tr>
<td>(P_T) (milliseconds)</td>
<td>7.7 ± 3.91</td>
<td>9.8 ± 5.0</td>
<td>.04</td>
</tr>
<tr>
<td>(P_{THM}) (milliseconds)</td>
<td>10.8 ± 4.95</td>
<td>15.3 ± 6.52</td>
<td>.001</td>
</tr>
<tr>
<td>(P_{RSA}) (milliseconds)</td>
<td>8.6 ± 6.06</td>
<td>14.2 ± 5.14</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>HR (percentage)</td>
<td>43.6 ± 23.88</td>
<td>23 ± 8.15</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Stress was associated with a significant increase in mean actual and intrinsic heart rate, and health risk (HR) in peacekeepers participating in PKM-BK, as compared to peacekeepers participating in PKM-A. Exposure to peacekeeper stress in Bosnia and Kosovo also resulted in significant decreases in mean values of mean RR interval, \(P_T\), \(P_{THM}\) and \(P_{RSA}\) compared to exposure to peacekeeper stress in Afghanistan. Peacekeepers participating in PKM-A showed decreases in the mean values of actual and intrinsic heart rate and increases in the mean values of \(P_{RSA}\), \(P_{THM}\), and STV.

Functional dependencies of physical stress on mental stress, health risk and heart rate

To examine the extent of stress reaction of peacekeepers participating in different PKM (1. Bosnia and Kosovo; 2. Afghanistan), both were examined at the re-deployment phase, actual and intrinsic heart rate, and HRV indices were compared between each condition by t-test. The mean values of actual and intrinsic heart rate, and HRV indices in peacekeepers at the re-deployment phase are presented in Table I.

**Table I.** Means (X±SD), and p-values of HRV indices, intrinsic and actual heart rate in re-deployment phase.

**Table II.** Regression equations of dependencies of PS on MS, HR and heart rate.

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<table>
<thead>
<tr>
<th>Dependence of PS on MS (MS, assessed with (P_T), (P_{THM}), (P_{RSA}))</th>
<th>PKM-BK</th>
<th>PKM-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_T) = 8.59 - 1.27* x PS</td>
<td>(B: p&lt;0.001)</td>
<td></td>
</tr>
<tr>
<td>(P_{THM}) = 12.13 - 1.87* x PS</td>
<td>(B: p&lt;0.001)</td>
<td></td>
</tr>
<tr>
<td>(P_{RSA}) = 10.3 - 2.39* x PS</td>
<td>(B: p&lt;0.001)</td>
<td></td>
</tr>
<tr>
<td>No dependence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependence of PS on HR</td>
<td>PKM-BK</td>
<td>PKM-A</td>
</tr>
<tr>
<td>HR = 34.63 + 12.59* x PS</td>
<td>(B: p&lt;0.001)</td>
<td></td>
</tr>
<tr>
<td>No dependence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependencies of PS on actual and intrinsic heart rate</td>
<td>PKM-BK</td>
<td>PKM-A</td>
</tr>
<tr>
<td>A-hr = 71.14 + 4.62* x PS</td>
<td>(B: p&lt;0.001)</td>
<td></td>
</tr>
<tr>
<td>I-hr = 103.1 + 6.7* x PS</td>
<td>(B: p&lt;0.001)</td>
<td></td>
</tr>
<tr>
<td>PKM-A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-hr = 75.38 + 14.25* x PS</td>
<td>(B: p= 0.018)</td>
<td></td>
</tr>
<tr>
<td>I-hr = 109.24 + 20.66* x PS</td>
<td>(B: p=0.018)</td>
<td></td>
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</tbody>
</table>
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In peacekeepers participating in PKM-A no regression dependence of physical stress (PS) on mental stress or of physical stress (PS) on health risk (HR) was found. In the second peacekeeper group-PKM-BK significant regression dependence of physical stress (PS) on mental stress and of physical stress (PS) on health risk (HR) were observed. In peacekeepers participating in PKM-A, and PKM-BK significant regression dependencies of physical stress (PS) on actual and intrinsic heart rate were observed. However the association between actual and intrinsic heart rate, and PS was more pronounced in peacekeepers participating in PKM-A than in peacekeepers participating in PKM-BK.

Results of interviews showed that peacekeepers participating in PKM in Bosnia, Kosovo, and Afghanistan were exposed to the following general types of stress: social and psychological stress (permanent maintenance of alertness and attention; work on day/night duties; deployment in new environment; provocations; consideration of the way of life, customs, and religion of the native population; separation from family; limited access to civilian places); risk of terrorism; potentially traumatic combat situations (incidents of combat attacks; dangerous patrols; safeguarding of important objectives; and increased risk of escalating conflicts).

Results of interviews showed also that peacekeepers participating in PKM in Afghanistan were exposed to the
following specific stressors associated with peacekeeping deployment: high altitude stress exposure and adaptation, specific psychological and social stressors related to leisure time, deployment in confined space groups without an exit option, living at camps, lack of diversity and contact with different people.

4. Discussion

Medical readiness is studied through medical surveillance and screening. In our study we analyzed medical surveillance through study of cardiac autonomic function, and medical screening through analysis of health risk. Medical readiness could be compromised during peacekeeping deployment phases when military personnel are exposed to stress.

The results of our study revealed that cardiac autonomic function and health risk are more affected by peacekeeping stress at the re-deployment phase in PKM-BK in comparison to the re-deployment phase in Afghanistan. Comparison showed increases of the mean values of actual and intrinsic heart rate, PS and MS, HR, and decreases of the mean values of mean RR interval, \( P_t \), \( P_{\text{THM}} \) and \( P_{\text{RSA}} \) in peacekeepers in Bosnia and Kosovo. These results indicate that peacekeeping stress in Bosnia and Kosovo induces a reduction of parasympathetic function and baroreceptor modulation of heart rhythm. We may assume that functional changes arise from the cumulative effect of risk of terrorist and combat attacks and threats, social and psychological stressors on cognition. The observed functional results are supported subjectively by personal interviews revealing exposure to simultaneous effects of peacekeeping stressors. Results of our study confirm the result of previous study [38] that the response pattern of peacekeeping stress is an integrated cognitive-functional cardiovascular response that prepares the organism to cope with the stressors. This result is also consistent with previous studies [11-15] describing the significance of cognitive appraisal of the stressor and its effect on health state. Our attempt to apply social and psychophysiological stress theories [16-18, 19] to analyze peacekeeping stress showed that the observed integrated cognitive-cardiovascular response (reduction in vagal cardiac function and lowered baroreflex modulation of heart rhythm [39,40] induced by the effect of stress on cognition) is an adaptive reaction to stress and is associated with active coping mechanisms coupled with a component of environmental intake information processing.

Comparison between PKM-BK and PKM-A showed that both groups were exposed to peacekeeping stress, according to the results from personal interviews. However the relationship between exposure to peacekeeping stressors and mental stress might be moderated by the high level of physical fitness in peacekeepers participating in PKM-A. A six-month peacekeeping deployment in Afghanistan was associated with daily maintenance of physical exercise of the peacekeeper’s own choice, which contributed to their high level of physical training. Physical fitness exercises were regularly and actively practiced and were perceived by peacekeepers as necessary for psycho-emotional unloading. This group did not reveal significant dependence of PS on MS assessed with frequency-domain HRV measures, or of PS on HR. In our study we also observed more pronounced significant regression dependence of PS on actual and intrinsic heart rate in peacekeepers participating in PKM-A. Both groups were physically trained. However the effect of regularly and actively practiced physical fitness exercises during deployment phase induced marked association between actual and intrinsic intrinsic heart rate, and PS in peacekeepers participating in PKM-A than in peacekeepers participating in PKM-BK. Physical exercises practiced during peacekeeping deployment in Afghanistan contributed to balance the effect of peacekeeping stress on the functional association between heart rate and PS. The adaptive anticipation response of heart rate-PS association pattern was induced by the effect of physical training.

In contrast, the first experimental group revealed significant dependence of PS on MS and of PS on HR. The positive relationship between PS and MS indicates that in peacekeepers participating in PKM-BK physical and mental stress increase simultaneously.

Results of our study of the moderating influence of physical training on the level of mental stress and of its protective effect on cardiovascular risk are consistent with the results of previous research [26] which indicated that physical training resulted in functional adaptation, and with the results of previous studies [28,29] revealing the protective effect of physical training on cardiovascular risk. As a consequence the integrated cognitive-functional cardiovascular response to peacekeeping stress in peacekeepers in Afghanistan might be viewed as an adaptive response, influenced by the effect of physical training. Results of our study showed that physical fitness acts as an anti-stress distracting mechanism.

We may assume that the mediating factor that induces physiological adaptation and leads to low levels of mental stress and non-increased cardiovascular risk in peacekeepers in Afghanistan is the effect of physical training on the imbalance between the tonic activity of the sympathetic and parasympathetic branches, reflected in prevailing vagal activity. In comparison to the peacekeepers participating in PKM-BK, peacekeepers participating in PKM-A showed increases in the mean value of \( P_{\text{RSA}} \) which is parasympathetically mediated, and decreases in the mean values of intrinsic and actual heart rate. Training induces changes in the response of intrinsic heart rate. Prevailing vagal activity decreases the slow diastolic depolarization rate of the S-A nodal cells and mediates the changes in intrinsic heart rate. The adaptive physiological role of training in decreasing the intrinsic rate of S-A nodal pacemaker tissue and in decreasing the intrinsic heart rate was reported in previous studies [23-27].

The increase in physical activity level enabled by good physical status was not related to increased mental stress or health risk. This result indicates that peacekeepers participating in PKM-A were characterized by psychological
readiness and stability (resilience and non-increased health risk) to the effects of peacekeeping stressors.

References


