J Biochem Tech (2019) (5): 89-95
ISSN: 0974-2328

Exam Stress and Immune Cells and Antibodies in Saudi Female University Students

Sawsan Mahassni, Afrah Abdullah Eskandar

Received: 11 August 2019 / Received in revised form: 04 December 2019, Accepted: 09 December 2019, Published online: 27 December 2019

Abstract

Stress leads to many changes in the body with some being advantageous while others are harmful. Findings of studies on the effects of acute stress in the form of academic final exams on the body are contradictory. This study determined the effects of exam stress on the immune system in 41 randomly chosen healthy Saudi female university students. All subjects filled a consent form and a questionnaire to categorize them into high and low-stress level groups. Blood samples were collected from the subjects on a day without final exams and later on a day of a final exam to determine the total and differential white blood cells (WBC) counts, and concentrations of cortisol and all immunoglobulin types. Results show that all subjects and subjects that felt a low-stress level had increased mean WBC, neutrophils, lymphocytes, and basophils cell counts; increased mean IgM and cortisol concentrations; decreased mean IgG concentration; and no change in the IgA, IgD, IgE concentrations for the exam period compared to the no exam period. Students that felt a high level of stress on the exam day, compared to the no exam period, had increased mean WBC and neutrophils cell counts, while cortisol and all antibodies concentrations were not different. Therefore, in conclusion, acute stress in the form of exam stress led to some enhancement of innate and acquired immunities, and some effects on humoral immunity and these changes occurred alongside increased cortisol levels. Additionally, subjects that felt a high-stress level showed fewer effects on innate and acquired immunities and no effects on humoral immunity compared to those who felt a low-stress level.

Key words: Stress, IgA, IgD, IgE

Introduction

Stress is the body's reaction to any physical, mental, or emotional tension or change. It is important for a quick response and survival during fight or flight situations. Stress is associated with increased mortality and risk for mental and physical ills and conditions, such as some types of cancer, cardiovascular diseases, asthma, chronic pain, autoimmune diseases, depression, anxiety, and metabolic disorders (Shields and Slavich 2017). Stress causes a feeling that the body is under an attack, which leads to many different effects and changes in the body. The effects of stress may be determined by observed physiological changes, such as increased heart rate, blood pressure, and stress hormones. Thus, stress may lead to hormonal, neuronal, behavioral, and other changes and it may negatively or positively affect the body and its systems, including the immune system (Morey et al. 2015). Stress may improve the body's functions and physical performance by increasing stamina, energy, strength, and focus and the brain works faster. On the other hand, it may negatively affect the body and its systems (Dhabhar 2014; Morey et al. 2015).

Stress may be classified, based on its duration, into chronic, acute, or episodic acute stress. The acute or short term stress is the stress that lasts for a few minutes to hours, while chronic, or long-term, stress lasts from several hours to days, weeks, or months. Stress also varies according to the intensity level. Stress may be caused by many different factors or stressors, which may be physical or psychological. Physical, or external, stressors are such as pain, illness, exercise, and smoking may lead to diseases. On the other hand, psychological, or internal, stressors are such as exams, divorce, and death of a loved one and they affect the pathogenesis of physical diseases by making a person more prone to unhealthy behaviors and lifestyle choices (Cohen et al., 2007).

The immune system is one of the systems that is affected by stress with both the innate and acquired immune systems being affected. In general, long-term or chronic stress may lead to harmful effects in the body while acute or short-term stress may be useful for enhancing and improving performance and it prepares the body for events that may harm the body (Dhabhar et al., 2010; Atanackovic et al., 2006). Stress may suppress or dysregulate both the innate and acquired immune systems of the body (Yang and Glaser, 2002; Kemeny and Schedlowski, 2007). Several previous studies (Segerstrom and Miller 2004; Kimura et al., 2005; Hussain, 2010) found that acute stress enhances the innate immune response while it suppresses the acquired immune response. On the other hand, it has been proposed that short-term (acute) stress enhances while long-term (chronic) stress dysregulates or suppresses both the innate and adaptive immune responses (Dhabhar, 2008). Also, it was found that acute stress suppresses cellular acquired immunity but does not affect humoral acquired immunity, while chronic stress suppresses cellular and humoral acquired immunity. These effects show in alterations in the counts and activity of immune cells, concentrations of antibodies, inflammation, increased/decreased susceptibility to infections, cancers, inflammatory diseases, autoimmune diseases, and other changes (Padgett and Glaser, 2003; Steptoe et al., 2007; Dhabhar, 2008; Dhabhar et al., 2010). Thus, stress may be immunoenhancing or immunosuppressive

Sawsan Mahassni, Afrah Abdullah Eskandar

Department of Biochemistry, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia.

depending on the type, intensity, and duration of the stress and stressor.

Stress can be measured and estimated by measuring the amount of blood cortisol or by the use of a questionnaire. Cortisol is a catabolic hormone that is secreted in response to stress. Therefore, it is a stress hormone and it is used as an indicator and biomarker for stress. Many questionnaires are available to measure and asses stress in subjects. One of the more commonly used questionnaires is the "Perceived Stress Questionnaire" (PSQ) developed by Levenstein et al. (1993). It is mainly concerned with quantifying cognitive and emotional stress by the individual.

Academic final examinations, which are considered an acute stressor, are a good way to study the effects of stress on subjects. This is because they are a real-life stressor that subjects take at the same time and has a set time. Final exams are considered a major stressor, possibly leading to mental and physical stress and anxiety. Studies (Weekes et al., 2006; Sadeghi et al. 2007; Shamsdin et al. 2010; Murphy et al. 2010) found increased cortisol levels in students taking exams, validating using cortisol levels as a marker for stress.

Previous human research studies on acute stress and its effects on the immune system and its components showed that stress increases blood counts of total white blood cells (WBC) (Jern et al. 1989; Patterson et al. 1995; Kondo and Morimoto 1996; Bhatti and Shaikh 2007), neutrophils (Pruett, 2003), monocytes (Pruett, 2003) and lymphocytes (Kondo and Morimoto 1996; Pruett, 2003). A study on exam stress in students (Segal, Brunob, and Forte 2006) found no effects on the blood concentrations of IgG, IgA, and IgM and lymphocyte subtypes counts, while in students that expressed high-stress blood concentrations of IgG, IgA, and IgM were increased (Maes et al. 1997). Another study (Mantur and Murthy 2010) on the effects of exam stress found increased counts of all WBC subsets. Other studies (Dhabhar, 2014; Dhabhar, 2008) showed that the counts of WBC increase at the beginning of stress but with the continued duration of stress, their numbers decrease and continue to be so as the stress continues.

As shown in previous studies, the findings on the effects of acute stress on the immune system are not contradictory. Therefore, it was the aim of this study to assess the effects of final exams stress (acute stress) on the immune system in Saudi female university students by determining the blood counts of total and subtypes of WBC and the serum concentrations of all types of antibodies.

Materials and Methods

Subjects

This study was carried out on 41 randomly chosen healthy Saudi female students, aged 19-26 years, from King Abdulaziz University, Jeddah, Saudi Arabia. None of the subjects were taking medications, pregnant, or menstruating at the time of blood collection. Also, none of the subjects had any major diseases, such as diabetes, high blood pressure, blood diseases, anemia, allergies, immunological diseases, and genetic diseases according to their answers on the questionnaire about health state.

The parameters were assessed in the group of students on two occasions: during the final examinations weeks (stressful period) and at the beginning of the term (stress-free period). All subjects filled a consent form and a questionnaire about their general health form. Also, subjects filled the Perceived Stress Questionnaire (PSQ), which is an approved questionnaire designed to assess the level of stress that a subject is experiencing (Levenstein et al., 1993), on the day of their final exam and blood sample collection.

Categorization of the Subjects

The subjects were categorized into two groups of stress levels in the examinations period using the total score from the Perceived Stress Questionnaire (PSQ) for each subject. A score that is less than 75 were considered as low stress, while a score equal to or higher than 75 was considered a high-stress group. The minimum score possible on the questionnaire is 30 and the maximum possible score is 120. Subsequently, the results for the two stress level groups were compared with the results for the same subjects (without another categorization) during the no final exams period.

Collection of Blood Samples

Blood samples were collected into two types of vacutainer tubes. Ethylenediamine tetra-acetic acid (EDTA) vacutainer tubes were used for whole blood for the differential complete blood counts (CBC), while plain vacutainer tubes were used for blood serum for the determination of the concentrations of antibodies and cortisol.

Blood in plain tubes was centrifuged at 3,000 rpm for 10 minutes to separate the serum from the blood clot. Subsequently, the separated serum was transferred into Eppendorf tubes and finally stored at -80°C until the tests were performed. EDTA vacutainer tubes were stored in a container containing ice for about 4 hours and then they were used.

Determination of the Differential Complete Blood Counts

The differential complete blood count (CBC) for all blood samples was done on a Coulter LH 700 Series (Beckman Coulter Inc., Brea, CA, USA) at the King Abdulaziz University Hospital, Jeddah, Saudi Arabia using the Coulter reagents according to the manufacturer's instructions.

Determination of Total Serum Cortisol Concentrations

A Monobind Cortisol ELISA Kit (Monobind Inc., Lake Forest, CA, USA) was used for the determination of total serum cortisol concentrations. The absorbance of the final product was read at 450 nm on a Microplate Reader ELX800 (Biotek Instruments,

Winooski, VT, USA) at the King Fahad Center for Medical Research.

Determination of Serum IgA, IgD, and IgE Concentrations

Serum IgA, IgD, and IgE concentrations were determined using a Total Human IgE Assay Kit, Total Human IgA Assay Kit (both Diagnostic Automation, Inc., Calabasas, LA, USA); and Total Human IgD Assay Kit (ALPCO Diagnostics, Salem, NH, USA). The absorbances for the final products were read at 450 nm on an ELX800 Microplate Reader (Biotek Instruments, Winooski, VT, USA) at the King Fahad Center for Medical Research.

Qualitative Determination of Serum IgG and IgM Concentrations

The qualitative determination of serum immunoglobulins IgG, and IgM concentrations was done by using IgG-ClC and IgM-ClC ELISA kits (DRG International, Inc. Mountainside, NJ, USA) and the absorbances of the final products were read at a 450 nm wavelength on a Microplate Reader ELX800 (Biotek Instruments, Winooski, VT, USA) at the King Fahad Center for Medical Research.

The kit determines whether the amount of antibody present in the sample is considered a significant amount or not. This is determined by calculating the standard deviation (sd) for the samples and the controls, provided in the kit, according to the instructions of the kit. Values of sd less than 2.0 are considered to be negative for significant levels of the antibody, while values of sd greater than or equal to 2.0 are considered to be positive for significant levels of the antibody.

Statistical analysis

The SPSS-V12 statistical program was used for descriptive and analytical statistics. The mean, standard deviation (± SD), and standard error of the mean (± SE) were calculated for all parameters. The paired sample t-test was used to compare the exam and no exam levels for all parameters except for the qualitative IgG and IgM levels where the Fisher's-test was used. The calculated P-value shows the presence of a highly significant difference (HS) when $P < 0.01$, a significant difference (S) when $P < 0.05$, and a none significant difference (NS) when $P \geq 0.05$.

Results

Results for the Uncategorized Subjects

The Differential Complete Blood Counts

The mean counts of the total WBC and their subtypes (neutrophils, eosinophils, basophils, lymphocytes, and monocytes) were determined for the two periods, as shown in Table 1. Using the paired samples t-test, the results showed a highly significant increase for the mean total WBC, neutrophil, and lymphocyte counts. No significant changes ($P > 0.05$) were found for the mean monocyte, eosinophil, and basophil cell counts for the stress case (final exam) compared to the mean counts for the no-stress case (no final exam).

Table 1: The comparison between the no final exam and final exam, using the paired samples t-test, for the mean differential CBC.

Cell count	No final exam	Final exam	P-value
($10^3/\mu L$)	Mean ± SD (± SE)	Mean ± SD (± SE)	
WBC	6.59 ± 1.93 (± 0.30)	7.95 ± 1.80 (± 0.28)	0.000^{HS}
Neutrophils	3.60 ± 1.39 (± 0.22)	4.60 ± 1.76 (± 0.27)	0.000^{HS}
Lymphocytes	2.30 ± 0.74 (± 0.12)	2.65 ± 0.77 (± 0.12)	0.001^{HS}
Monocytes	0.50 ± 0.27 (± 0.04)	0.49 ± .21 (± 0.03)	0.959^{NS}
Eosinophils	0.16 ± 0.14 (± 0.02)	0.16 ± 0.13 (± 0.02)	0.881^{NS}
Basophils	0.02 ± 0.04 (± 0.01)	0.03 ± 0.05 (± 0.01)	0.200^{NS}

Serum levels of Cortisol and Antibodies

The mean serum level of cortisol for the stress case (Table 2) increased highly significantly compared to the mean level for the no-stress case, using the paired samples t-test. There were no significant differences, using the paired samples t-test, between the final and no final examination mean serum IgA, IgD, and IgE levels. On the other hand, using the Fisher's test (Table 3), the mean serum IgM concentration for the final exam samples increased significantly compared to the no final exam mean level, while the mean IgG level for the final exam period decreased highly significantly compared to the no exam period mean level.

Table 2: The comparison between the no final exam and final exam, using the paired samples t-test, for the mean serum cortisol, IgA, IgD, and IgE levels.

Concentration	No final exam	Final exam	P-value
	Mean ± SD (± SE)	Mean ± SD (± SE)	
Cortisol	8.54 ± 4.66 (± 0.73)	12.20 ± 4.62 (± 0.72)	0.001^{HS}
(μg/dL)			
IgA	4.19 ± 8.69 (± 1.36)	2.88 ± 10.04 (± 1.57)	0.535^{NS}
(μg/dL)			
IgD	47.75 ± 60.37 (± 10.67)	46.32 ± 40.78 (±7.21)	0.825^{NS}
(ng/mL)			
IgE	164.29 ± 219.03 (± 34.21)	180.56 ± 212.43 (± 33.18)	0.504^{NS}
(IU/mL)			

Table 3: The comparison between the no final exam and final exam, using the Fisher's test, for the significant and non-significant counts for the mean serum IgM and IgG levels.

Antibodies (mg/dL)	No final exam		Final exam		P-value
	Number of samples		Number of samples		
	significant	non-significant	significant	non-significant	
IgM	3	38	5	36	0.035^{S}
IgG	8	33	7	34	0.001^{HS}

Results for the Categorized Subjects

Categorization of the Subjects:

The subjects were categorized into two groups of stress levels (low and high stress levels) based on the score on the Perceived Stress Questionnaire (PSQ) during the exams period. The low-stress group had 29 subjects (70.7% of total subjects) and the high-stress group had 12 (29.3%). The parameters were compared between the no final exam and final exam periods for each stress level group separately.

The Differential Complete Blood Counts

Comparing the mean WBC counts for each stress level group between the no exam and exam periods (Table 4), using the paired samples t-test, the mean WBC counts for the low and high stress levels, and the mean neutrophil count for the high-stress level increased highly significantly compared to the respective mean counts for the no final exam period. The mean neutrophil count for the high-stress group, mean lymphocyte count for the low-stress group and mean basophil count for the low-stress group all increased significantly compared to the respective mean counts for the no final exam period. The mean counts for both stress level groups for the monocytes and eosinophil, the mean count for the high-stress level group for both the lymphocytes and basophil cells (Table 4) were not significantly different from the respective mean counts for the no final exam period.

Table 4: The comparison between the no final exam and final exam for each stress level group separately, using the paired samples t-test, for the mean differential CBC.

Cell count	Stress level	No final exam	Final exam	P-value
($10^3/\mu L$)		Mean ± SD (± SE)	Mean ± SD (± SE)	
WBC	Low	6.51 ± 1.96 (± 0.37)	7.74 ± 1.69 (± 0.31)	0.001^{HS}
	High	6.77 ± 1.92 (± 0.56)	8.46 ± 2.03 (± 0.59)	0.003^{HS}
Neutrophils	Low	3.53 ± 1.46 (± 0.27)	4.44 ± 1.82 (± 0.34)	0.005^{HS}
	High	3.75 ± 1.25 (± 0.36)	4.98 ± 1.61 (± 0.47)	0.010^{S}
Lymphocytes	Low	2.26 ± 0.78 (± 0.14)	2.62 ± 0.78 (± 0.15)	0.010^{S}
	High	2.39 ± 0.67 (± 0.19)	2.72 ± 0.76 (± 0.22)	0.052^{NS}
Monocytes	Low	0.52 ± 0.30 (± 0.06)	0.48 ± 0.22 (± 0.04)	0.529^{NS}
	High	0.44 ± 0.17 (± 0.05)	0.53 ± 0.18 (± 0.05)	0.233^{NS}
Eosinophils	Low	0.17 ± 0.15 (± 0.03)	0.16 ± 0.12 (± 0.02)	0.712^{NS}
	High	0.15 ± 0.12 (± 0.03)	0.16 ± 0.16 (± 0.05)	0.809^{NS}

Basophils	Low	0.021 ± 0.041 (± 0.008)	0.024 ± 0.044 (± 0.008)	0.010^{S}
	High	0.02 ± 0.04 (± 0.01)	0.05 ± 0.05 (± 0.02)	0.052^{NS}

Serum Levels of Cortisol and Antibodies

Using the paired samples t-test (Table 5), the mean serum cortisol concentration for the low-stress group in the final exam period increased highly significantly compared to the mean level for the same group in the no final exam period, while there was no significant change in the mean cortisol concentrations for the high-stress group for the two periods. As for the mean serum IgA, IgD, IgE, using the paired samples t-test (Table 5), and IgM concentrations (results not shown), using the Fisher's test, for both stress level groups, there were no significant differences between the concentrations for the final exam and no final exam periods. However, the mean serum IgG concentration for the low-stress level group for the exam period decreased highly significantly compared to the mean concentration for the no exam period, while for the high-stress level group there was no significant difference between the two periods (results not shown).

Table 5: The comparison between the no final exam and final exam for each stress level group separately, using the paired samples t-test, for the mean serum cortisol, IgA, IgD, and IgE levels.

Concentration	Stress level	No final examination	Final examination	P-value
		Mean ± SD (± SE)	Mean ± SD (± SE)	
Cortisol	Low	8.84 ± 3.84 (± 0.71)	12.07 ± 4.02 (± 0.75)	0.005^{HS}
(µg/dL)	High	7.83 ± 6.39 (± 1.85)	12.53 ± 6.02 (± 1.74)	0.092^{NS}
IgA	Low	3.49 ± 7.59 (± 1.41)	3.63 ± 11.87 (± 2.20)	0.956^{NS}
(µg/dL)	High	5.89 ± 11.10 (± 3.21)	1.07 ± 1.68 (± 0.49)	0.159^{NS}
IgD	Low	54.33 ± 69.73 (± 14.54)	45.62 ± 43.45 (± 9.06)	0.240^{NS}
(ng/mL)	High	30.93 ± 17.53 (± 5.84)	48.12 ± 35.32 (± 11.77)	0.184^{NS}
IgE	Low	161.97 ± 238.14 (± 44.22)	180.73 ± 226.95 (± 42.14)	0.549^{NS}
(IU/mL)	High	169.90 ± 173.33 (± 50.04)	180.15 ± 181.63 (± 52.43)	0.786^{NS}

Discussion

Academic examinations represent one of the stressful events associated with a lowered immune system function and they have been used in stress research because they are predictable, standardized, and discrete examples of real-life stressors (Shamsdin et al., 2010). The research work presented here was aimed at studying the effect of examinations stress on the immune system of female university students.

The parameters measured for the subjects of the study were assessed at a stressful time (exams period) and a non-stressful time or condition (regular lectures, non-exams period). Also, the subjects were classified into two stress level groups, which were low and high stress groups, according to a cutoff score on the Perceived Stress Questionnaire that was filled in the exams period.

In the first section of the results, highly significant increases were observed for the mean counts of the total WBC (Non-exam period Mean ± SD: 6.59 ± 1.93, Exam period Mean ± SD: 7.95 ± 1.80), neutrophils (3.60 ± 1.39, 4.60 ± 1.76), and lymphocytes (2.30 ± 0.74, 2.65 ± 0.77) for the exams readings compared to the non-exams case (control). The mean monocytes, eosinophils, and basophils counts were not significantly different between the exam and no exam periods.

In the second section of the results, the low-stress level group had significantly increased mean counts of the total WBC (6.51 ± 1.96, 7.74 ± 1.69), neutrophils (from 3.53 ± 1.46 to 4.44 ± 1.82), and lymphocyte (from 2.26 ± 0.78 to 2.62 ± 0.78), and basophile (from 0.021 ± 0.041 to 0.024 ± 0.044) for the final exam period compared to the no final exam period. The high-stress level group showed significant increases in the mean counts for the total WBC (6.77 ± 1.92, 8.46 ± 2.03) and neutrophils (3.75 ± 1.25, 4.98 ± 1.61) for the final exams period compared to the no final exam period. The mean monocytes and eosinophils cell counts did not show any significant differences between the periods for both stress level groups and the high-stress level group for the mean basophils count.

The observed increased cell counts during the examination period agree with the findings of previous research studies. This increase in WBC and its subtypes counts may be due to the brain sending signals to reverse the stress reaction leading to the secretion of stress hormones, which modulate the immune system by increasing leukocyte trafficking and this is observed clearly in the results of final exams period. This is similar to the study of Pruett

(2003), which concluded that stress might lead to changes in the counts of WBC and increases in the blood counts of neutrophils, monocytes, and lymphocytes. In another study (Bhatti and Shaikh, 2007), physiological stress (exercise stress) led to significant increases in total WBC counts in both male and female students. On the other hand, the effects of stress which have been reported in studies on fish, amphibians, reptiles, birds, mice, rats, rabbits, foxes, horses, non-human primates, and humans showed a reduction in WBC counts (Dhabhar, 2014). In contrast to animal studies, human studies have shown that stress can increase rather than decrease blood leukocyte numbers (Dhabhar, 2008).

In this study, the mean cortisol concentration, compared to the no examination period, was highly significantly increased in the subjects in the exams period (8.54 ± 4.66, 12.20 ± 4.62) and for the low-stress level for the exams period (8.84 ± 3.84, 12.07 ± 4.02). The increase in the cortisol hormone during the stressful exams period is expected since it is a stress hormone, which is used as a biomarker of stress and thus it is especially elevated during stressful situations. Also, it is known that the concentration of cortisol is at its highest level in the morning and its lowest level a few hours after going to sleep. Both blood collections were done in the morning to avoid this fluctuation in the cortisol levels.

In agreement with our findings is the study done by Shamsdin et al. (2010) to determine the effect of exam stress on serum cortisol level showed that exam stress resulted in a significant increase in the cortisol level. In contrast to our results is the study was done by Weekes et al. (2006) on undergraduate students which observed no significant correlations between elevations in psychological measures of stress and elevations in cortisol levels, thus no evidence was found to suggest a relationship between psychological and hormonal levels of stress.

The results show no significant changes ($P \geq 0.05$) in mean serum IgE, IgA and IgD concentrations for the two results sections. There was a significant increase ($P = 0.035$) for the mean IgM concentration and a highly significant decrease ($P = 0.001$) in the mean IgG concentration for the exam period compared to the non-exam period. Also, there was a highly significant decrease ($P = 0.003$) in the mean IgG concentration for the low-stress level group but no significant differences for the high stress level for the mean IgG concentration and both stress level groups for the mean IgM concentrations during the exam period compared the mean concentration for the low-stress level for the no exam period.

A study that was done by Segal, Brunob, and Forte (2006) on medical students concluded that there were no alterations in the IgA, IgG and IgM serum levels during acute stress, which agrees with our findings for IgA but not for IgG and IgM. Also in disagreement with the results, the concentration of IgG in mice increased after acute stress and decreased in chronic stress (Silberman Wald, and Genaro 2003). Whereas a study (Shao et al., 2003) on rats exposed to emotional stress led to decreased IgG levels in agreement with our results. A study on students exposed to examination stress showed a significant decrease in IgM but no significant changes for IgA, IgG or IgE (Vassend and Halvorsen, 1987), while another study (Shamsdin et al. 2010) on exam stress showed decreased IgE levels.

In summary, acute stress in the form of final examinations led to increased mean blood WBC, neutrophils, lymphocytes, and basophils cell counts; increased mean serum IgM and cortisol concentrations; and decreased mean serum IgG concentration compared to the respective counts and concentrations for the no exam period. Whereas for students feeling a high level of stress, the only difference in the parameters between the no exam and exam period was increased mean blood WBC and neutrophils cell counts for the exam period, while cortisol and all antibodies concentrations were not different. For all subjects and both stress levels, the mean serum concentrations for IgA, IgD, IgE did not change between the two periods.

Thus, it may be concluded that acute stress leads to the increased counts of some innate (WBC, neutrophils, and basophils) and acquired (WBC, and lymphocytes) immunity cells, and some effects on humoral immunity (increased IgM, and decreased IgG concentrations). Also, these changes occurred together with increased cortisol levels. Subjects that felt a high stress level showed fewer changes in the measured parameters than those who felt a low-stress level.

It is recommended that further studies be carried out on a larger number of subjects and male students. This would help to determine if there are gender differences in response to stress. It is also recommended to construct a stress questionnaire that may be more appropriate for the local population.

Funding:

This research study was partially funded by a grant provided by King Abdulaziz City of Science and Technology.

References

Atanackovic, D., Schnee, B., Schuch, G., Faltz, C., Schulze, J., Weber, C., Schafhausen, P., Bartels, K., Bokemeyer, C., Brunner-Weinzierl M. & Deter, H. (2006) Acute Psychological Stress Alerts the Adaptive Immune Response: Stress-Induced Mobilization of Effector T Cells. *Journal of Neuroimmunology, 176*, 141-152.

Bhatti, R. & Shaikh, D. (2007) The Effect of Exercise on Blood Parameters. *Pakistan Journal of Physiology, 3*, 44-46.

Cohen, S., Janicki-Deverts, D. & Miller, G. (2007) Psychological Stress and Disease. *The Journal of the American Medical Association, 298*, 1685-1687.

Dhabhar, F. (2008) Enhancing Versus Suppressive Effects of Stress on Immune Function: Implications for Immunoprotection Versus Immunopathology. *Allergy, Asthma and Clinical Immunology, 4*, 2-11.

Dhabhar, F. S. (2014) Effects of stress on immune function: the good, the bad, and the beautiful. *Immunol Res., 58*(2-5), 193–210.

Dhabhar, F., Saul, A., Daugherty, C., Holmes, T., Bouley, D. & Oberyszyn, T. (2010) Short-Term Stress Enhances Cellular Immunity and Increases Early Resistance to Squamous Cell Carcinoma. *Brain, Behavior, and Immunity, 24*, 127-137.

Hussain D. (2010). Stress, Immunity, and Health: Research Findings and Implications. *International Journal of Psychosocial Rehabilitation, 15*, 94-100.

Jern, C., Wadenvik, H., Mark, H., Hallgren, J. & Jern, S. (1989) Haematological Changes During Acute Mental Stress. *British Journal of Haematology, 71*, 153-156.

Kemeny, M. & Schedlowski, M. (2007) Understanding the Interaction Between Psychosocial Stress and Immune-Related Diseases: A Stepwise Progression. *Brain, Behavior, and Immunity, 21*: 1009-1018.

Kimura, K., Isowa, T., Ohira, H. & Murashima, S. (2005) Temporal Variation of Acute Stress Responses in Sympathetic Nervous and Immune Systems. *Biological Psychology, 70*: 131-139.

Kondo, H. & Morimoto, K. (1996) Effects of Mental Arithmetic Stress on Blood Cell Counts and The Immune System. *Environmental Health and Preventive Medicine, 1*: 76-79.

Levenstein, S., Prantera, C., Varvo, V., Scribano, M., Berto, E., Luzi, C. & Andreoli, C. (1993) Development of the Perceived Stress Questionnaire: A New Tool for Psychosomatic Research. *Journal of Psychosomatic Research, 37*: 19-32.

Maes, M., Hendriks, D., Van Gastel, A., Demedts, P., Wauters, A., Neels, H., Janca, A. &Scharpe, S. (1997) Effects of Psychological Stress on Serum Immunoglobulin, Complement and Acute Phase Protein Concentrations in Normal Volunteers. *Psychoneuoendocrinology, 22*: 397-409.

Mantur, S. & Murthy, C. (2010) Effects of Academic Stress on Leukocyte Subset Distribution in Humans. *Journal of Chinese Clinical Medicine, 5*: 516-519.

Morey, J. N., Boggero, I. A., Scott, A. B., & Segerstrom, S. C. (2015) Current Directions in Stress and Human Immune Function. *Curr Opin Psychol., 5*: 13-17.

Murphy, L., Denis, R., Ward, C. & Tartar, J. (2010) Academic Stress Differentially Influences Perceived Stress, Salivary Cortisol, and Immunoglobulin-A in Undergraduate Students. *Stress, 13*: 366-371.

Padgett, D. & Glaser, R. (2003) How Stress Influences the Immune Response. Trends *in Immunology, 24*: 444-448.

Patterson, S., Matthews, K., Allen, M. & Owens, J. (1995) Stress-Induced Hemoconcentration of Blood Cells and Lipids in Healthy Women During Acute Psychological Stress. *Health Psychology, 14*: 319-324.

Pruett, S. (2003) Stress and the Immune System. *Pathophysiology, 9*: 133-153.

Sadeghi, Z., Eidi, M., Eidi, A. & Bahar, M. (2007) Effects of Practical Examination Stress on Serum ACTH and Cortisol Concentrations in Normal and Anxious Students. *Journal of Medical Sciences, v. 7*: 489-491.

Segal, A., Brunob, S. & Forte, W. (2006) Immune Function in Acute Stress. *Allergol Immunopathol, 34*: 136-140.

Segerstrom, S. & Miller, G (2004) Psychological Stress and the Human Immune System: A Meta-Analytic Study of 30 Years of Inquiry. *Psychological Bulletin, 130*: 601-630.

Shamsdin, S. Anvar, M. & Mehrabani, D. (2010) The Effect of Exam Stress on Serum IL-6, Cortisol, CRP and IgE Levels. *Iranian Red Crescent Medical Journal, 12*: 484-488.

Shao, F., Lin, W., Wang, W., Washington, W. & Zheng, L. (2003) The Effect of Emotional Stress on The Primary Humoral Immunity of Rats. *Journal of Psychopharmacol, 17*: 179-183.

Shields, G. S., & Slavich, G. M. (2017) Lifetime stress exposure and health: A review of contemporary assessment methods and biological mechanisms. *Social and Personality Psychology Compass, 11*(8): e12335.

Silberman, D., Wald, M. & Genaro, A. (2003) Acute and Chronic Stress Exert Effects on Antibody Responses Associated with Changes in Stress Opposing Hormone Regulation of T-Lymphocyte Reactivity. *Journal of Neuroimmunology, 144*: 53-60.

Steptoe, A., Hamer, M., & Chida, Y. (2007) The Effects of Acute Psychological Stress on Circulating Inflammatory Factors in Humans: A Review and Meta-Analysis. *Brain, Behavior, and Immunity, 21*: 901-912.

Vassend, O. &d Halvorsen R. (1987) Personality, Examination Stress and Serum Concentrations of Immunoglobulins. *Scandinavian Journal of Psychology, 28*: 233-241.

Weekes, N., Lewis, R., Patel, F., Garrison-Jakel, J., Berger, D. & Lupien, S. (2006) Examination Stress As An Ecological Inducer of Cortisol and Psychological Responses to Stress in Undergraduate Students. *Stress, 9*: 199-206.

Yang, E. & Glaser, R. (2002) Stress-Induced Immunomodulation and the Implications for Health. *International Immunopharmacology, 2*: 315- 324.