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CONTENTS

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Dropout rate during prolonged physical stress training in the military may be determined by haematological changes

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Sustained physical training has profound effects on haematological adaptive changes and these may influence physical performance, the dropout rates and casualties in a military setting. Prompted by reports of increases in the number of dropouts during military training, the impact of haematological changes on dropout rates and physical performance was studied in 60 male Zimbabwe National Army (ZNA) recruits during 60 days of military training at the Nyanga training camp. The training programme included, among other things, bush exercises in the rugged terrain of the Nyangani range of mountains. Blood for full blood count (FBC) were collected by venepuncture in a forearm vein in a seated position two weeks pre-training (day zero). Subsequent samples were collected at seven, 30 and 60 days. FBC analyses was carried out by Sysmex K800 (Kobe, Japan) and urine samples were analyzed for urobilinogen. The results showed significant decreases in the red blood cells (RBC) and haemoglobin (Hb) ($P<0.05$) and ($P<0.04$) on day seven and day 30 respectively when compared to day zero. The persistent increase in haematocrit throughout the 60 days suggested haemoconcentration and a fall in plasma volume (PV). When compared to pre-training, granulocytes were significantly higher on day 60 than on day 30 ($P<0.004$). Lymphocytes and eosinophils were lower on day seven ($P<0.001$) when compared to day zero and ($P<0.04$) and ($P<0.013$) when compared to day 30 and 60 respectively, suggesting that the subjects had a decreased protection against infection. However, lymphocytes were higher on day 60 than on day seven ($P<0.01$). This observed recovery in lymphocytes on day 60 when compared to day seven and 30, suggested that acclimatization and adaptation had occurred. Of the 60 subjects, 18 percent were hospitalized [four with

pulmonary TB and a hypochromasia blood picture while three had bronchopneumonia and a raised neutrophil count]. The number of dropouts was 16 (27 percent) of the 60 subjects under study. Laboratory observations showed proteinuria, a shift to the left in the myeloid series, nucleated red blood cells, platelet clumps, macrocytosis and red cell fragments. These were associated with casualties, dropouts and poor physical performance. These results suggested that severe haematological changes might be associated with poor performance, high rates of casualties and dropouts. Therefore, monitoring the trends of haematological changes at regular intervals during stress training can minimize casualties and the rates of dropouts.

Keywords: **macrocytosis, dropouts, haemoconcentration, hypochromasia.**

Introduction

In the military, physical fitness is considered to be an important element for combat readiness. To meet this requirement, soldiers undertake strenuous physical exercise in diverse stressful environments. For example, in the Zimbabwe Defence Forces, soldiers train under heat stress conditions in the Kariba basin and the cold and mountainous terrain in the Nyanga general area. Also, individuals in athletic and other occupational settings may be required to perform physical exercise in stressful conditions during which dehydration, exertional heatstroke (EH), injury and infections often occur and can be life threatening for the soldier and athlete (Mudambo, 1996).

Mudambo (1996) studied soldiers during prolonged exercise in the heat and found significant haemoglobinuria in some subjects. In the same study, it was also observed that on day 30 of exercise, red blood cell count had decreased significantly compared to day one and that some of the subjects were producing dark urine. Several factors have been suggested which are likely to result in dark urine: first, when blood myoglobin concentration rises to a range above 300 μg/ml, renal threshold is exceeded and myoglobin is excreted into urine, thereby producing a colour ranging from of light "iced tea" to a darker coca-cola colour (Clarkson, 1993). Secondly, there is a breakdown of red blood cells as well as bleeding from the bladder and gut. "March haemoglobinuria" has also been implicated mainly due to destruction of the blood capillaries under the soles of the feet when soldiers are involved in long marches and prolonged training (Erslev, 1995). However, observations from other studies show that during long term training, increased red blood cell production over compensates for this destruction (Davidson, 1964).

Although the impact of exercise on immune function and haematological changes has been studied extensively (Singh et al., 1964; Foster et al., 1986, Schmidt et al., 1986; Erslev, 1995), the impact of these changes on performance and dropout rates requires further study. Thus, the aim of this study was to investigate further the impact of prolonged physical stress on haematological changes and, in turn, how these affect performance and dropout rates of military trainees. It was hoped that the current investigation on the effects of training on haematological changes would add to the body of evidence on haematological changes.

It was hypothesized that although in man there is a range of haematological factors which may change due to physical exercise and environmental conditions, these are likely to be modified by the intensity and duration of exercise and emotional stress.

Materials and Methods

Subjects and Experimental Design

Subjects

The subjects were 60 healthy Zimbabwe Defence Forces recruits randomly selected from a group of 105 volunteers who were undergoing 60 days recruit training at the Nyanga training base. Pre-recruitment medical examination included chest X-ray and laboratory tests for FBC, and screening for diabetes, cardiovascular conditions, HIV-seropositive (HIVSP), hepatitis, tuberculosis (TB) and sexually transmitted infections. These were carried out one month before training started, according to the Zimbabwe Defence Forces Health Services recruitment regulations. All the 60 subjects were found to be free from any of the diseases/conditions and fit for training. During these medical screening tests, each subject was issued with a medical file (for recording illness and injury). Baseline blood samples for the current research project were collected two weeks prior to the onset of any military training (day zero) and subsequent samples were collected at seven, 30, and 60 days during the training period. All subjects were non-smokers and throughout the training period, the recruits had the same living conditions, diet and daily activities. The volunteers gave their informed consent after being briefed of the benefits and effects of the study and that they were free to leave the study at any time without adverse effects. The study protocol was approved by the Defence Forces Health Services Research and Ethics Committee and the Ethics Committee for the University of Zimbabwe Medical School.

Physical training

The recruits went through the routine military training programme which included, among other things, drill and sports (soccer and volleyball). Outside of the training programme there was no time for the recruits to engage in their individual extracurricular recreational or sporting activities.

Physical performance

Performance was assessed by running time, ability to carry 30 kg during route marches, and ability to complete a certain number of exercises per minute. For example, one was required to complete a 400 metre run in 50 seconds, 45 sit ups, 30 push ups, and 30 squats per minute^{-1}.

Medical attrition

Information on infections suffered during the 60 day training period was extracted from the individual medical records compiled by health care professionals who were not part of the research group. These records included the diagnosis, treatment given, number of days missed training, referrals to hospitals, number of days in hospital and removal from training on medical grounds. A follow up was made at the hospital on all those subjects who were hospitalized for more than one week. Information on subjects who were removed from training for administrative reasons or failure to cope with training was extracted from the camp administration records. Any trainee who stayed in hospital for more than three days was removed from training (this is in line with the training standing orders).

Blood sampling and analyses

All blood samples were collected in a seated position by venepuncture using a forearm vein without stasis. On the sampling day, subjects reported to the medical post at 0700 hours after an over night fast. They were made to rest in a seated position for 30 minutes before blood was collected. At each sampling occasion, five ml of blood were collected into EDTA tubes for full blood count (FBC) analysis by Sysmex SX 3000 (TOA Medical Electronics Co, Kobe Japan).

Urine sampling and analysis

First void mid-stream urine samples were collected in urine jars on day seven, 30 and 60. All those subjects producing a dark red urine sample were monitored for urinobilinogen (proteinuria and haematuria) and haemoglobinuria. Observations were done visually and also under microscope after centrifugation.

Statistics

Analysis was conducted using EPI-INFO 6.0 and Statgraphics version 5.0 standard statistical packages. Linear regression was used to determine correlations and comparison for differences due to sampling phases (i.e. effects of training and duration). Values are reported as mean (SEM). $P<0.05$ was considered statistically significant. The results reported in this paper are those of 44 subjects because 16 subjects were removed from training.

Results

Throughout the training period, haematocrit remained significantly increased from mean (SEM) 46 (0.4) to 51 (0.78) percent, 54 (0.66) and to 49 (0.39) ($P<0.01$) ($P<0.001$), ($P<0.02$) when day seven, day 30 and day 60 are compared to day zero respectively (Figure 1). Granulocytes increased significantly (P<0.003) when day 30 was compared to day zero. Lymphocytes and eosinophils were significantly (P<0.01), (P<0.03) and (P<0.05) lower on day seven, 30 and 60 compared to day zero. As shown in Figure 2, lymphocytes were significantly lower on day seven, day 30 and day 60, ANOVA, P<0.001; P<0.03 and P<0.05 respectively when compared to day zero. Figure 2 further shows that on day seven [22 (2) percent] lymphocytes were significantly lower than day 30 [24 (3) percent] ANOVA, P<0.04 and day 60 [26 (one) percent] ANOVA, P<0.013. Granulocytes were higher on day 60 when compared to day seven and 30 (P<0.004).

Figure 3 shows that red blood cells decreased significantly (P<0.05) on day seven and (P<0.04) day 30 and remained decreased throughout the 60 days training period. Haemoglobin also decreased significantly (P<0.04) indicating that the subjects had developed anaemia.

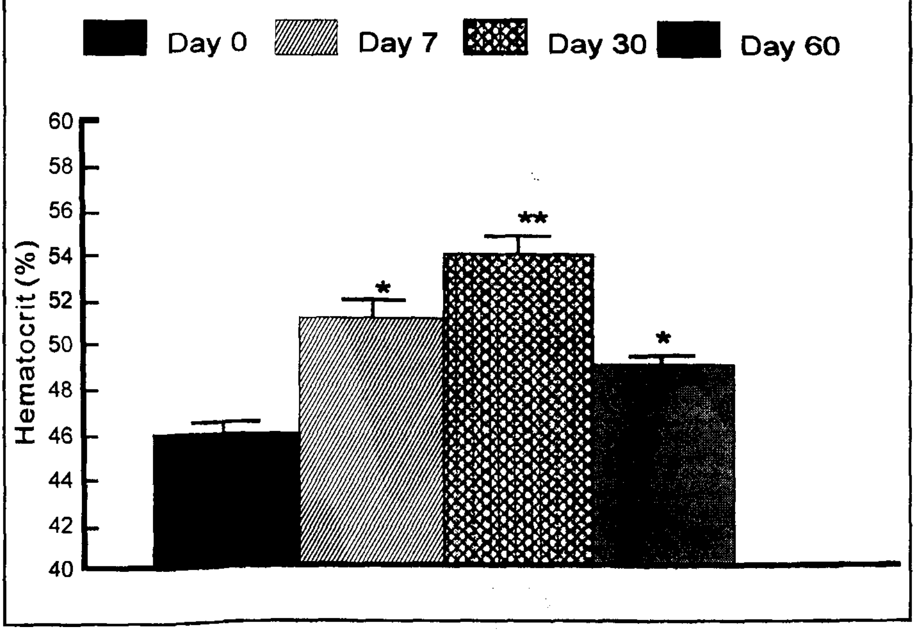

Figure 1: Effects of training on haematocrit. Values are mean (SEM), n = 44. Significantly higher when day seven, day 30 and day 60 is compared to day zero, (ANOVA, *P<0.02, **P<0.001 and *P<0.02) respectively.

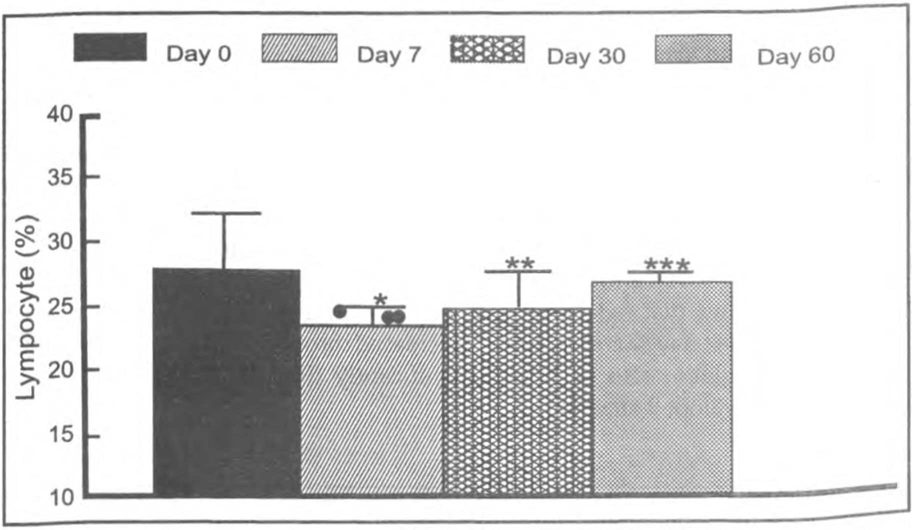

Figure 2. Effects of training on lymphocytes. Values are mean (SEM), n = 44. Significantly lower on day 7, Day 30 and day 60, (ANOVA, *P<0.001, **P<0.02, ***P<0.05) respectively when compared to day zero. Significantly lower on day 7, (ANOVA, IP<0.04 and IIP<0.013) compared to day 30 and day 60 respectively.

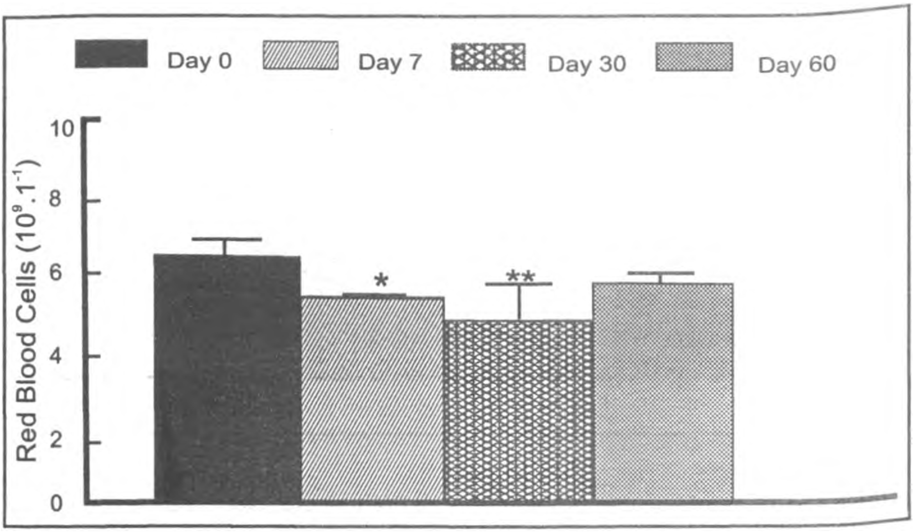

Figure 3. Effects of training on red blood cells. Values are mean (SEM), n = 44. Significantly lower on day seven and day 30, (ANOVA, *P<0.05 and **P<0.04) respectively when compared to day zero.

Medical attrition/ dropout rates/ impaired performance

Of the 60 subjects, 11 (18 percent) were hospitalized due to a combination of the following: macrocytosis, platelet clumps, red blood cell fragments, nucleated red blood cells, anaemia, protenuria, TB (four subjects) and pneumonia (three subjects) (Table 1 compares the baseline haematological parameters with those taken on the day of discharge of the 16 dropouts). The results showed significant decreases in neutrophils, monocytes, lymphocytes and abnormal distribution of platelets and red blood cells. All the 11 subjects were removed from training because they had spent more than three days in hospital. The discharge on medical grounds accounted for 81.3 percent of the total discharged (13/16) while impaired performance and administrative removal accounted for 12.5 and 6.3 percent respectively. Post discharge follow up of subjects revealed that three of the TB cases and two of the pneumonia cases had developed full-blown AIDS. Thus, HIV/AIDS accounted for 38.5 percent of the discharge on medical grounds and 31.3 percent of the total discharge.

Table 1: Hematological parameters of the 16 dropouts.

Parameter	Day O (baseline)	Day discharged	P value
HCT (percent)	46 (0.8)	34.9 (2.7)	P<0.001
HGB (g/dl)	15 (0.6)	11.8 (0.8)	P<0.03)
RBC (10^6/ul)	6.2 (0.3)	3.7 (0.9)	P<0.04
WBC (10^3/L)	7.3 (0.1)	3.96 (0.6)	P<0.05
Lymphocyte (percent)	2.58 (0.4)	0.96 (1.3)	P<0.03
Neutrophil (percent)	0.58 (0.05)	0.37 (0.9)	P<0.05
Monocyte (percent)	0.65 (0.02)	0.34 (1.1)	P<0.04
Platelets (10^3/ul)	327 (5.6)	188 (8.2)	P<0.01
Eosinophil (percent)	0.38 (0.07)	0.13 (0.3)	P<0.05

Values are mean (SEM): n=16; P value significantly different from baselin

Dropouts were observed between day seven and 30 of training. No dropouts were observed after day 30 suggesting that acclimatization had occurred. Of the 60 subjects, 16 (26.7 percent) were discharged from training: 13 (21.7 percent) were removed on medical grounds, two (3.3 percent) due to impaired physical performance and one (1.7 percent) for administrative reasons. Thus, 3.3 percent of the subjects were removed from training because they had slow running times, failure to complete tasks, failure to lift or carry the prescribed weights, poor mental alertness and had frequent attacks of cramps of the calf muscle.

Discussion

This study has provided a number of answers and results, which ought to help understand further the effects of haematological changes on performance during prolonged exercise under stressful conditions. The study revealed that during 60 days of training, haematological changes in some of the subjects severely affected their performance. An interesting result of the present study is that laboratory and clinical observations revealed that 13 subjects developed a combination of either of the following: proteinuria, platelets clumps, red cell fragments, nucleated red blood cells (NRBC), macrocytosis, hypochromasia and in some cases blasts and macrocytosis, TB and pneumonia. The results further showed significant decreases in platelets (also showed abnormal distribution), RBC, WBC, lymphocytes, monocytes neutrophils and eosinophils suggesting that immune function was severely suppressed. Therefore, the infections (such as TB, pneumonia, abscesses) which affected the dropouts and led to the medical discharges are a result of this failure to boost immune function during exercise. This severely impaired their performance.

The impact of the prolonged physical stress resulted in microangiopathic haemolytic anaemia (MAHA) and disseminated intravascular coagulopathies, factor (III) being released in the system which resulted in platelet clamping besides the anaemia. These severe changes would decrease the blood volume and ability to meet the cardiovascular strain associated with exercise and consequently lead to an early onset of fatigue. Therefore, the results of the present study suggest that failure to cope with exercise in our subjects is related to the observed changes in haematological parameters.

Erslev in 1995 observed "march haemoglobinuria" in some subjects and attributed this to the breakdown of red blood cells by traumatic tension. Results of the present study which are similar to those of an earlier study by Mudambo (1996), seem to suggest that the red blood cell fragments which remained in the system for some time are the likely causes of capillary clogging. Thus, the destruction of red blood cells in the foot capillaries when soldiers are running (Davidson, 1964) and the consequent clogging of capillaries, effectively decreases the oxygen available for energy conversion in conditions where there is increased muscular oxygen extraction, which leads to an increased production of 2,3-diphosphoglycerate and a shift of the oxygen dissociation curve to a right-shifted (Hallberg and Magnuson, 1984) as observed in the present study. While this shift would improve the delivery of oxygen to the tissues, it will effectively decrease erythropoetin production and reset haemoglobin concentration to a lower level (Davidson, 1964; Hallberg and Magnusson, 1984). This decreases muscle oxygen consumption and depletes the energy output resulting in severe detriment in performance as observed in our subjects.

The observed haemoconcentration suggests a fall in plasma volume as observed before by Mudambo *et al.*, 1999 who observed a 16 percent fall in plasma volume during prolonged exercise in the heat. Thus, the fall in plasma volume further suggests a possible shunting of blood from the splanchnic system so as to maintain adequate supply to the exercising muscle. A simpler explanation would be dehydration. Because the blood supply to the gut is decreased, the delivery of nutrients to replenish the falls in blood glucose concentration and to meet the high energy demands of the exercising muscle is adversely affected and this leads to fatigue, delayed recovery in between exercise bouts, muscle cramps especially of the calf, and a possible onset of exertional heatstroke (EH). Such a scenario would lead to a multisystem failure, that is, body fluid shifts and a fall in plasma volume due to dehydration (Mudambo 1994), body mass loss, plasma electrolyte imbalance, haemoconcentration and inadequate tissue perfusion which adversely affects muscle energy metabolism. Our argument here is that if environmental conditions (air temperature, relative humidity or wet bulb globe temperature) and individual clinical chemistries are monitored regularly, it is possible to predict those individuals likely to become casualties and this, therefore, would decrease the dropout rates. Also, adequate nutrition and fluid supply, introducing work rest regimes, good emergency follow up and supportive therapy (for example, control of seizures, acid-base-balance, re-hydration), and understanding the etiological paradigms of exertion, will help reduce the rates of attrition.

An important question raised here is, why after medical screening HIVSP was observed within a short period of starting training. Is this because the screening programme is not sensitive enough or that some subjects escaped the screening programme. This requires further investigation.

Conclusion

The results of the present study suggested that severe haematological changes may be associated with poor physical performance, casualties, microangiopathic haemolytic anaemia and dropouts. The results further strengthen our earlier observation that HIVSP is a struggle against adaptation during prolonged exercise. Monitoring the trends of haematological changes during stress training can be an effective surveillance for minimizing medical attrition and as an early predictor of probable casualties and dropouts. These results further suggested that in man there is a range of haematological factors, which may change due to physical exercise, but these may be modified by emotional stress and environmental conditions, and this is likely to affect the general performance of the subjects.

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