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Physiological and biochemical responses during incremental uphill load carriage

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ABSTRACT

The present study aimed to examine the effect of carrying different magnitudes of load on the changes and relationships of salivary Immunoglobulin A (IgA) and cortisol concentrations and the physiological parameters. Twelve Indian soldiers performed an intense uphill treadmill walking at two speeds viz. 2.5 km h^{-1} and 4 km h^{-1} without any load and carrying 10.7 kg, 17 kg and 21.4 kg loads for 36 min. Salivary IgA concentration relative to total protein decreased significantly after each exercise session and cortisol concentration increased concomitantly with physiological variables e.g. heart rate (HR), oxygen consumption (VO_2), minute ventilation (VE) and energy expenditure (EE). An inverse correlation ($P < 0.05$) was observed between IgA with HR for all the conditions except when the participants walked at 4 km h^{-1} carrying 17 kg and 21.4 kg load. The degree and type of physiological and biochemical responses may help in designing combat training, operations and developing preventive strategies of military personnel involving intense exercise.

Relevance to industry: Walking with load in incremental uphill terrain is highly stressful and fatiguing. Results of the present study will help in designing training schedules for maintaining the optimal fitness of an individual during uphill walking with loads in different speeds.

1. Introduction

Military personnel carry loads on various terrains and altitudes under different environmental conditions during deployment and training sessions. Carrying heavy load is a demanding activity which involves strenuous physical exercise. Such stress not only results in decreased military performance but also causes fatigue, mood disturbances, frequent upper respiratory tract infection (URTI), muscle injury and joint pain. High intensity exercise stimulates the hypothalamic- pituitary- adrenal (HPA) axis and the sympathoadrenal medullary (SAM) system (Usui et al., 2012). Previous studies have reported that an increased HPA axis activity is associated with the subsequent rise in salivary cortisol level due to acute stress (Rahman et al., 2010). Salivary IgA (Immunoglobulin A) may be regarded as a sensitive and quantitative index of the SAM system activity (Allgrove et al., 2008). Tomasi et al. (1982) first observed decreased concentration of salivary IgA (sIgA) in cross country skiing performers which has been subsequently supported by many other studies (MacKinnon et al., 1989; Mackinnon et al., 1993; Muns et al., 1989). These evidences till date suggest that strenuous physical activity causes transient immunosuppression and therefore athletes and military personnel who undergo intense training may have a higher incidence of URTI. There are very few studies that have investigated the effect of physical exertion and stress caused by load carriage on immune function and cortisol level in the military perspective (Pacque et al., 2002; Morgan et al., 2000). Pacque et al. (2002) reported that high intensity physical activity causes decreased concentration of IgA in Australian army population. Morgan et al. (2000) observed the response of 109 American soldiers to intense acute stress in the form of U.S. Army survival training and found a significant increase in cortisol level. Several studies suggest during exercise increased cortisol secretion

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Table 1
Demographic and morphological informations (n = 12).

Parameters	Mean ± SD
Age (years)	27.1 ± 3.6
Height (cm)	170.3 ± 4.0
Weight (kg)	66.2 ± 6.4
Working experience (years)	7.7 ± 3.9
BMI (kg/m^2)	22.6 ± 2.0
Fat %	7.8 ± 7.1

BMI – Body mass index.

Table 2
The experimental loads and their various components.

Load (kg)	Components	% of body weight
10.7	HS, 4.4 kg + web, 2.1 kg + INSAS Rifle, 4.2 kg	16.11
17	BP, 10.7 kg + web, 2.1 kg + INSAS Rifle, 4.2 kg	25.60
21.4	BP, 10.7 kg + web, 2.1 kg + INSAS Rifle, 4.2 kg + HS, 4.4 kg	32.22

may lead to immunosuppression (Gleeson, 2007; Ronsen et al., 2001).

The mucosal immune system protects surfaces of the respiratory and gastrointestinal tracts exposed to the environment and especially IgA is considered as the first barrier to infection by microorganisms causing URTI (Gleeson and Pyne, 2000). The major function of IgA is to inhibit the attachment and replication of pathogenic microorganisms, thus preventing colonization by these pathogens (Lehner, 1992). Studies have shown that intense endurance exercise decreases the concentration of IgA contained in mucosal secretions such as saliva and nasal fluids (Muns et al., 1989) and may remain depressed for several hours after intense endurance exercise (MacKinnon et al., 1989). Recently, during a lumbar flexion/extension task interleukin-6 (IL6) increased with increase of external load, whereas creatine kinase (CK) increased with increase in load as well as the frequency of the task (Christian and Naussbaum, 2015). Previously, it was demonstrated that an increase in IL6 and CK concentration is associated with muscle inflammation and injury (Bruunsgaard et al., 1997).

Cortisol is widely accepted to be the physiological indicator of stress (de Kloet et al., 2005). Estimation of salivary cortisol is regarded as a reliable reflector of the serum cortisol levels (Obminski and Stupnicki, 1997). Infact for stress response salivary cortisol gives a better measure of stress than serum cortisol as saliva contains free cortisol (Vining et al., 1983). Therefore measuring of salivary cortisol levels is a regular practice to detect the effect of stress induced due to intense physical activity in an

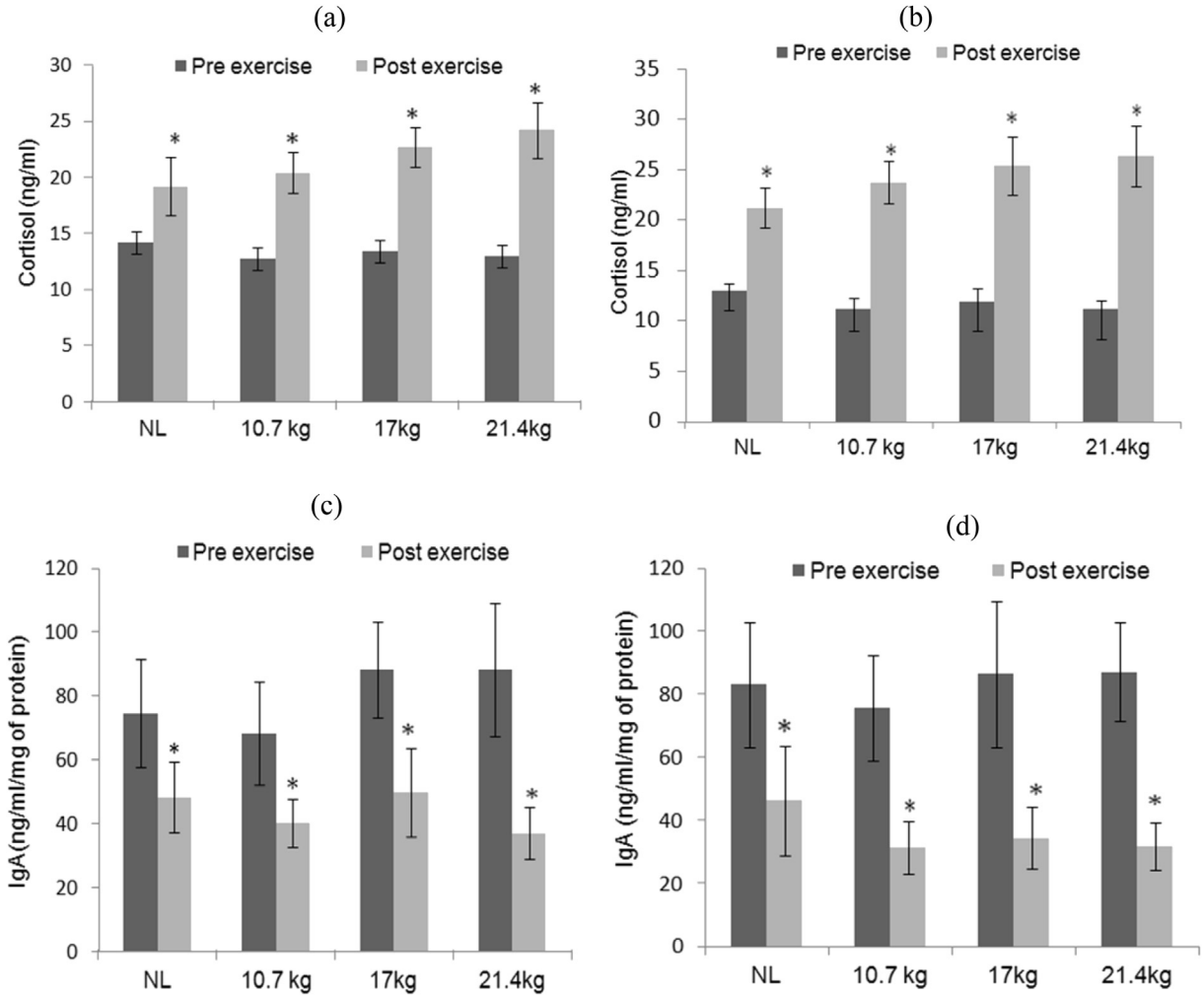

Fig. 1. Effect of exercise on changes in salivary (a) cortisol concentration (ng/ml) at 2.5 km h^{-1} speed (b) cortisol concentration (ng/ml) at 4.0 km h^{-1} speed (c) IgA concentration (ng/ml/mg of protein) at 2.5 km h^{-1} speed (d) IgA concentration (ng/ml/mg of protein) at 4.0 km h^{-1} speed during pre and post exercise load carriage. Values are expressed as mean ± SEM, n = 12. Significant difference with respect to main effects of time was observed for each condition (*p < 0.05) when two way ANOVA for repeated measures was computed.