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Muscular Responses to different magnitude of load carriage and uphill-downhill grade combinations and its effect on cortisol concentration in Indian Soldiers

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Introduction

The fundamental necessity for human walking is the appropriate activation of leg muscles in response to changing conditions. For example, walking uphill and downhill is a common part of many of our daily activities. Walking involves a variety of biomechanical processes, and electromyographic recordings offer some insight into how the neuromuscular system adapts to such actions. It is generally acknowledged that cortisol is the physiological marker of stress, and testing salivary cortisol levels is a common procedure to identify the impact of stress brought on by vigorous physical exercise on an individual. During deployment and training, Indian soldiers must carry loads and hike up and down steep mountain slopes in the Himalayas. This is an unavoidable aspect of military life. This study investigated how the muscle activities and cortisol responses were affected by various magnitudes of load along with incremental-decremental gradients while walking on a treadmill.

Methodology

Twelve healthy male Indian soldiers aged 24.8±2.9 yrs, height: 173.76±7.4cm and weighing 66.2±6.4kg were the participants included in the present study. In this experiment participants walked continuously for 1 hr in each uphill and downhill gradient for 6 mins. Total duration of walk was 6 mins x 10 gradients, i.e. 60 mins. All the participants walked at 3kmhr^{-1} speed carrying load of 0.0 kg, 10.7 kg and 21.4 kg. They walked initially uphill at 0%, 5%, 10%, 15% and 20% gradients before moving on to gradients of -20%, -15%, -10%, -5%, and 0% downhill. Every participant completed 3 continuous uphill and downhill (1 speed x 3 loads x 1 gradient protocol) load carriage experiments on 3 different days. During each experiment the activities of Erector spinae (ES) and

Vastus medialis (VM), of both sides were monitored by surface Electromyography along with the pre-test and post-test concentration of salivary Cortisol.

Result

Significant effects of gradient on the knee extensors were observed. Load and gradient had a significant effect on ES muscles activity, along with Cortisol concentration. It was observed that while walking with 21.4kg loads at 3km.h^{-1} speed the activity of both the muscles and Cortisol concentration increased maximally compared to other conditions. The activity of the muscles viz. ES increased up to 252% during uphill walking. In case of VM muscles, downhill walking had more effect on the muscle's activity than uphill walking [Right Vastus medialis (RVM): 290%, Left Vastus medialis (LVM): 280%]. When walking at a 3 kmhr^{-1} speed unloaded, the cortisol concentration was raised by 22%, and when walking at the same speed with a 21.4 kg burden, it climbed by 77%. As the influence of time was taken into account, the exercise-induced stress resulted in a considerable rise in cortisol concentration as compared to pre-exercise settings.

Conclusion

This form of strenuous activity especially on the knee extensors predisposes the risk of muscular injury and early onset of fatigue. An increase in cortisol levels was also observed, indicating the level of stress that had been induced. Hence, the combat fitness of the military personnel may be reduced. Military training schedule should therefore be designed accordingly to reduce the incidence of injuries.

Keywords: Muscular responses, Load Carriage, Walking Uphill-Downhill, Cortisol concentration.

Introduction

The country's hilly border regions are protected by thousands of Indian soldiers who are stationed in the western and eastern regions. For reaching those harsh, desolate places, they have to overcome several challenges, like hiking up and down slopes that are inaccessible to wheeled vehicles and the risk that the sounds of their vehicles will alert enemy soldiers. Due to mission requirements and limited transportation capacity, soldiers often have to transfer various pieces of equipment according to their level of mobility. They must also transport a variety of cargoes, including food, water, ammunitions, communication devices, and other supplies. In these extremely taxing mountainous terrains, Indian infantry soldiers must carry out physically hard missions while being mobile, deadly, and undiscovered. Running and walking are both impacted by gradients. Walking or running uphill is more taxing and demanding than running downhill, and it consumes more energy when done so (Santee et al., 2001). Running and walking downhill both involve negative work, which lowers the energy cost by shifting the body's center of mass vertically downward.

There are some military objectives which demand that soldiers march as quickly and painlessly as possible, with the least amount of fatigue (Johnson et al., 1995). The soldiers experience significant physiological, muscular, biochemical, and psychological strains due to poor walking speed and load combinations. Moreover, these already taxing demands may get worser if the speed and load are not adjusted to variations in gradient. Excessively physically taxed soldiers will be worn out and more likely to sustain injuries. Reynolds et al. (1990) observed that a soldier's weariness and injuries had a negative impact on their combat preparedness, which in turn affects the mission's effectiveness. Thus, for understanding the load carriage impacts, it is imperative that critical elements like walking speed and gradient type be analyzed in a simulated environment.

The musculoskeletal system of the load carrier is subjected to added stress when carrying substantial loads (Harman et al., 2000), which raises the possibility of musculoskeletal damage. In addition to the financial costs associated with treating such injuries, Orr et al. (2011) stated that suffering from such injuries can impair military personnel's performance by reducing their force generation and maintenance capacity. Soldier injuries during combat operations can lower the unit's overall combat efficacy (Butler, 2008). However, the military force will be more effective if any injury prevention measures are taken than when the same force would be devoid of it (Butler, 2008). Studies related to electromyography (EMG) have provided evidence on the precise moment and intensity of muscular activities throughout human locomotion. Prior research has demonstrated that EMG recordings offer important insights into the responses of the muscles to varying levels of weight carrying when walking at different grades-speeds combinations (Knapik et al., 1996; Franz and Kram, 2012; Silder et al., 2012; Lindner et al., 2012).

The occupational demands of the military personnel require lifting of heavy objects while doing various activities in hazardous environments. The physiological strain for bearing an occupational load rises in tandem with its weight (Knapik et al., 2004). Lumbar ES (Erector spinae) muscle activity got raised because of front pack load carriage but while carrying load in the double pack the muscle was unaltered and, in the backpack, the muscular activity decreased. Thus, the placement of the load on the trunk appeared to be directly associated to the extent of activation of the back and abdominal muscles during standing. These findings, however, do not explicate on how load placement affects walking. A handful of electromyographic studies have been done to examine how different muscles are affected by backpack weight (Bobet and Norman, 1984; Holewijen, 1990; Harman et al., 1992). These investigations have confirmed that the mass of the carried load impacts the trunk muscles activity.

According to previous studies, it had been observed that as the military load amplified from 20 to 47 kg, there was a rise in average quadriceps and gastrocnemius activity (Harman et al., 2000). The stimulation of the ES and trapezius muscles was influenced by the weight bearing systems that were supported on the hips (Knapik et al., 1996). Fouad et al. (2001) proposed that, when perturbations were applied, the stimuli elicited a substantial compensatory response in the muscles viz. RGM (right gastrocnemius medialis) and RSOL (right soleus), but in case of the unperturbed LGM (left gastrocnemius medialis) muscles, EMG activity did not follow the adaption patterns. The repeated disturbances that were administered in their experiment caused an induced reflex response in the plantar flexors.

For the military personnel traversing through various terrains via walking, jogging, climbing, or even crawling may present unsolicited challenges. An individual’s capacity to bear a burden can be significantly impacted by terrain elements such as surface type, grade, and other factors. The fundamental requirement for controlling human movement is the capacity to suitably engage lower limb muscles in response to environmental deviations. For instance, walking up and down hills is a daily activity that requires very different biomechanics for many of us (Lay et al., 2006). EMG recordings can elucidate how the neuromuscular system adapts to this action. There is a scantiness of research in relation to the activation of muscles during walking in incremental or decremental gradients, and provides inadequate insight into the muscle recruitment strategies employed (Lay et al., 2007). When walking uphill or downhill, more muscle contractions are needed to elevate or lower the centre of mass (CoM), respectively, in comparison to level walking. Lay et al. (2007) detected EMG signals from the leg muscles during walking at steep elevations and descents (37%). They found that when walking at the same speed uphill, extensor muscle activations in the hip, knee, and ankle increased, but in case of downhill walking only extensor muscles of the knee increased. According to Fouad et al. (2001), body weight is not the only factor that determines how much force is applied to the limbs but is also influenced by the terrain (walking uphill or downhill) and the postural state, such as whether the person is running or strolling.

Load carriage is an arduous task requiring intense physical exertion. Exercise activates the hypothalamic-pituitary-adrenal (HPA) axis and the sympathoadrenal medullary (SAM) system (Leal-Cerro et al., 2003). According to earlier research, acute stress causes a rise in cortisol levels in the saliva, which is correlated with an increased HPA axis activity (Rahman et al., 2010). Cortisol is a glucocorticoid which is produced by the adrenal cortex having several key roles, including aiding in gluconeogenesis, both before and after exercise (Hackney, 2008). It is commonly acknowledged that cortisol serves as a physiological marker of stress as was also reported by de Kloet et al., 2005. Cortisol levels in saliva are thought to be a good indicator of cortisol levels in serum (Obminski and Stupnicki, 1997). In fact, because saliva contains free cortisol, salivary cortisol measures stress better than serum cortisol (Vining et al., 1983). As a result, testing cortisol levels in saliva is a common procedure to identify the impact of stress brought on by vigorous physical exercise on an individual. Additionally, it has been noted that depending on the type of exercise, acute exercise alters the plasma cortisol concentration (Jacks et al., 2002), activity duration and intensity, the proportion of anaerobic to aerobic activity, body fat percentage, and the subject's level of fitness are other variables that affect cortisol responses (Azizi et al., 2012). When 109 American soldiers received severe acute stress training through the U.S. Army, Morgan et al. (2000) evaluated how they responded and discovered a significant increase in cortisol levels.

According to what the author is aware of, there hasn't been any research done on the Indian military personnel that examines and measures biochemical and muscle activation patterns as a result of carrying weight on various uphill-downhill gradients. Thus, in order to replicate load carriage operations that Indian soldiers perform in field settings on both uphill and downhill gradients, the current study was designed in a laboratory setting. This allowed us to measure the effects of increasing load magnitudes on specific muscular and biochemical variables of a group of Indian military personnel. The loads carried by the soldiers in this study (0.0 kg, 10.7 kg and 21.4 kg) may not seem particularly heavy, but their combined impact on the cardiovascular system, skeleto-muscular system, and specific biochemical stress parameters on long-term exposure in field conditions was thought to be worthwhile investigating in order to develop a plan for improving the soldiers' performance and lowering their risk of injury.

The present study's objective was to ascertain the effect of carrying different magnitudes of load and walking in various uphill-downhill gradients on muscular responses viz. right erector spinae (RES), left erector spinae (LES), right vastus medialis (RVM), left vastus medialis (LVM) and Cortisol concentration.

Methods

Background information of the participants

Some elementary information like age (27.1±3.6 yrs) and work experience (7.7±3.9 yrs) were gathered from every male participant prior to the beginning of the experiment. An electronic stadiometer (Model- 220, Seca Germany) was used in the early morning to assess the subjects' height and weight when they were wearing very little clothing by standardised techniques. Assessment of body composition was done by the bioelectrical impedance method by body composition analyzer (Tanita body composition analyzer, TBF-310, Japan). The average height (170.3±4.0 cm), weight (66.2±6.4kg) and body mass index (22.6±2.0 kg/m^2) of all the participants were also recorded.

Experimental load combinations

The load magnitudes chosen for this study were 0.0 kg, 10.7kg, and 21.4kg. Indian infantry soldiers carry comparable loads in the field, either alone or in conjunction with the afore-mentioned loads. These combinations of loads were used for this study to replicate comparable laboratory settings. The participants carried weights of 10.7 kg that was around 16.1% of bodyweight (BW) and 21.4 kg which was 32.2% body weight in the existing load carriage ensemble of the Indian Army the details of which can be found in the research article published by Paul et al., 2016, as this is a part of the larger study.

Electromyographic Measurements

The sEMG (surface electromyographic) signals were recorded at a frequency of 1024 Hz from muscles viz. ES (Erector spinae) at L3 region (Right Erector spinae [RES] and Left Erector spinae [LES]) and Vastus medialis [VM] (Right Vastus medialis [RVM] and Left Vastus medialis [LVM]) bilaterally, by the Delsys myomonitor IV EMG system (Delsys Inc., Boston MA). The skin preparation of each participant was given special attention before the pre-amplified, single differential surface electrodes (Trigno, Delsys, Inc., Boston MA) were placed. If the volunteer had facial hair, it was carefully shaved off, the skin was cleansed with alcohol, and it was allowed to dry naturally. The pre-amplified electrodes were applied to the muscle bellies in compliance with Cram and Kasman's (1998) guidelines after the skin was prepared. When the participants contracted each muscle, the electrode position was confirmed and the signal quality was examined visually. Every EMG signal (20–450 Hz) was automatically band pass filtered by the Delsys hardware. Using the Delsys software, the EMG data for each muscle were fully wave rectified and smoothed through the application of root mean square (RMS) calculation. Average sEMG data of the last 30 seconds exercise in each of the 0%, ±5%, ±10%, ±15%, and ±20% gradients were considered as distinct value for further analysis. The mean amplitude of the 0% treadmill walking data was used to normalize all of the EMG data for gradients of ±5%, ±10%, ±15%, and ±20%.

Cortisol Concentration measurement

As directed by the manufacturer, the salivary cortisol ELISA kit (Diagnostics Biochem Canada Inc.) was utilized to quantify the cortisol levels in the samples of saliva.

Experimental Protocol

In this experiment the participants walked continuously for 1 hr in each uphill and downhill gradient for 6 mins. Total duration of walk was 6 mins x 10 gradients, i.e. 60 mins. They walked at a pace of 3kmhr^{-1} carrying 0.0kg, 10.7kg and 21.4kg load. They began by walking at gradients of 0%, 5%, 10%, 15%, and 20% uphill. Next, they walked at gradients of -20%, -15%, -10%, -5%, and 0% downhill. Each participant was subjected to 3 continuous uphill and downhill (1 speed x 3 loads x 1 gradient protocol) load carriage experiments on 3 different days.

Statistical analysis of the data

SPSS 23.0 for Windows (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL69606-6412) was used to compute all statistical analyses. The standard error of the mean (SEM) and mean values for each descriptive statistics were displayed. The design of the experiment was repeated measures. A two-way repeated measure ANOVA was used, with a significance level of $P<0.05$, to determine the impact of the independent variables which are load and gradient, on the experimental dependent variables, which were the muscular activities of the RES, LES, RVM, and LVM muscles. A Bonferroni post hoc test was used to determine the pairwise differences if the F-ratio was significant. A two-way repeated measure ANOVA was performed, and the main pair effects between the trials and times were compared using a Bonferroni post-hoc analysis, in order to determine the impact of independent variables on cortisol. The time x trial interaction was also accounted. Significant values were identified at the $P<0.05$ level. In this experiment Cortisol was measured at two-time intervals viz. at 0th minute (pre exercise) and at 60th minute (post exercise). Trial and time were thus the two independent variables in the study. There were two levels for time and three levels for the trial. As a result, there were three (3 x 1) distinct experimental trials. Table 1 provides a thorough description of each trial.

Independent variables	Levels	Experimental conditions
Trial	Trial 1	NL (no load)+ 3.0 kmhr^{-1}
	Trial 2	17 kg + 3.0 kmhr^{-1}
	Trial 3	21.4 kg + 3.0 kmhr^{-1}
Time	0th minute	Pre exercise
	60th minute	Post exercise

Table 1: Stipulation of the experimental independent variable (Cortisol)

Results

EMG activity as affected by load and gradient

Erector Spinae (right and left) muscle

All the volunteers accomplished the various modes of treadmill walking protocol in all the gradients while walking unloaded and carrying 10.7 kg and 21.4kg loads for an hour. The RES and the LES muscles activities increased as the weight carried in the load carriage ensemble increased. These muscle activities also increased with increasing uphill gradients while carrying 10.7 kg and 21.4 kg loads in comparison to NL. The effect of load [F (2, 22) = 4.224, p= 0.000 ($p<0.05$)] on the RES activity was significant as seen in Figure 1 (A). Post-hoc analysis showed that a significant relation exists between the grades ($p<0.05$). LES activity showed an almost similar response and was found to be significantly affected by load [F (4, 44) = 22.763, p= 0.000 ($p<0.05$)] as was seen in Figure 1 (B).

It was observed that as the subject walked at progressively uphill grades the activity of these muscles increased. As they walked in decremental gradients the activity of both the muscles decreased compared to the uphill gradients. When walking at $3kmhr^{-1}$ without any load, both ES muscles exhibited an average increase in activity of about 26% at a 5% gradient. When walking at the same speed at 20% gradient, however, they demonstrated an average increase in activity of roughly 250% when compared to their respective loads at a 0% gradient. The RES and LES muscle activity were shown to be lower when walking downhill from 20% to 0% compared to their corresponding uphill gradients. Significant effect of grade [F (1.574, 17.310) = 25.124, p= 0.000 ($p<0.05$)] on the RES activity was observed. The Bonferroni post-hoc test computed showed significant relations between the grades ($p<0.05$), as noticed in table 77. The LES muscle activity was also significantly affected by grade [F (4, 44) = 22.763, p= 0.000 ($p<0.05$)]. Additionally, post-hoc analysis revealed a significant relationship ($p<0.05$) between the grades. The load, gradient, and speed interaction effects did not exhibit any significance.

Figure 1 (A)

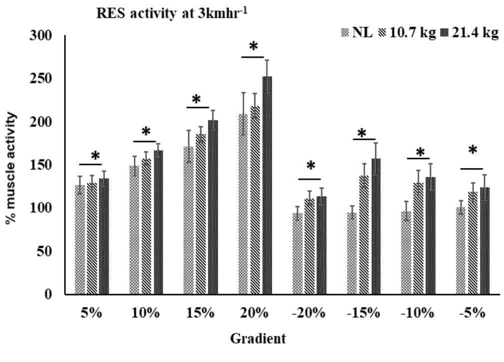

Figure 1(B)

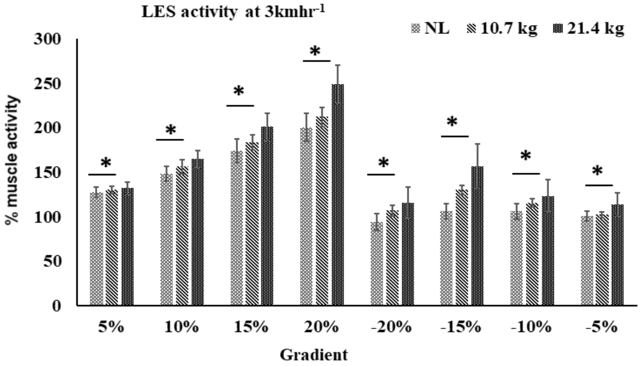

Figure 1: Effect of continuous uphill-downhill walking on changes in (A) RES activity at 3kmhr^{-1} (B) LES activity at 3kmhr^{-1}

Vastus medialis (right and left) muscle

An increase in the load and gradient lead to the augmented activity of the the knee extensor in both the lower limbs consistently [Figures 2(A) and 2(B)]. For all gradients, the activities of these muscles increased as the load rose, although the influence of the load on these activities was not statistically significant.

When walking unloaded at 3 km/h, there was an average 24% increase in activity at a 5% gradient, and at the maximum uphill grade and load combination, there was an approximate 272% increase in activity compared to their respective loads at 0% gradient. On the other hand, there was an average 284% increase in muscle activity when the patients began walking downhill from 20% to 0%. There was a significant effect of grade [F (1.712, 18.827) = 25.017, p= 0.000 ($p<0.05$)] on RVM activity [Figure 2 (A)]. There were significant relations among almost all the grades ($p<0.05$) as computed by the Bonferonni analysis. Grade also had a significant impact on LVM activity [F (2.261, 24.873) = 67.873, p= 0.000 ($p<0.05$)]. [Figure 2 (B)]. Load and grade interaction effect was not significant.

Figure 2 (A)

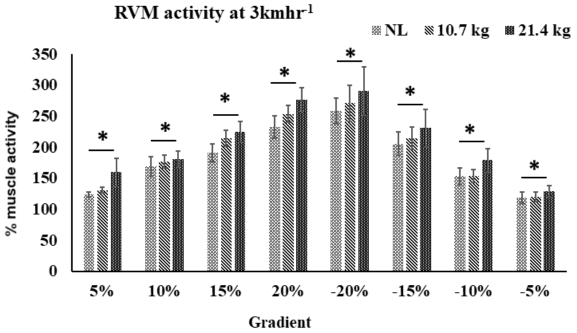

Figure 2 (B)

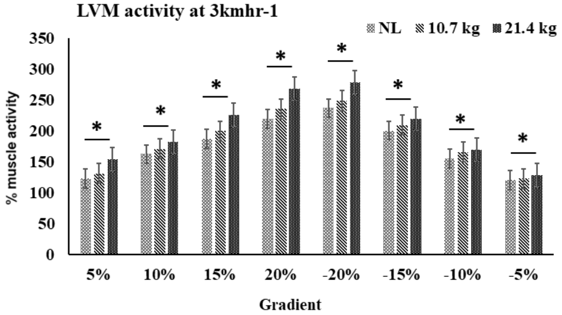

Figure 2: Effect of continuous uphill-downhill walking on changes in (A) RVM activity at 3kmhr^{-1} (B) LVM activity at 3kmhr^{-1}

Salivary Cortisol levels

When compared to pre-exercise conditions, the cortisol concentration augmented in the range of 22% (when walking without a weight at a speed of 3kmhr^{-1}) to 77% (while walking with a load of 21.4 kg at a speed of 3kmhr^{-1}) (Figure 3). When the influence of time was taken into account, the exercise-induced stress resulted in a substantial rise in cortisol concentration [F (1, 11) = 56.177, p=0.000, $p<0.05$]. According to post-hoc analysis, there were significant changes in cortisol levels between 0th min and 60th min of the trials (p=0.000, $p<0.05$). A significant trial x time interaction effect was also found [F (2, 22) = 6.476, p=0.006, $p<0.05$]. (Figure 3).

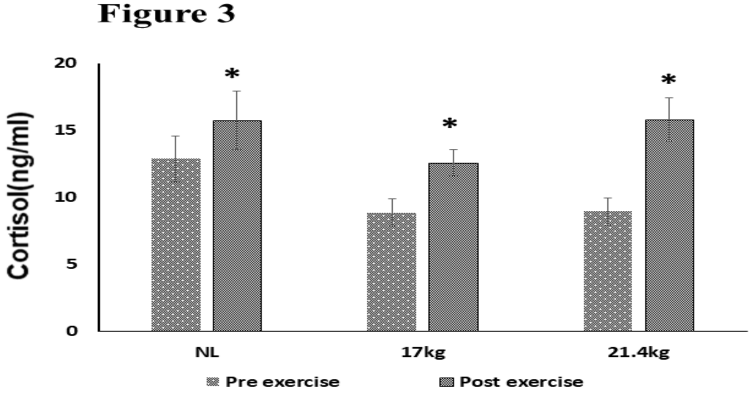

Figure 3: Effect of continuous uphill-downhill walking on variations of cortisol levels in saliva at 3kmhr^{-1}

Discussion

According to Johnson et al. (1995), soldiers must accomplish certain military objectives by completing marches as soon as feasible with the least amount of weariness and suffering. Inadequate walking speed and load combinations can cause military soldiers to experience extreme muscle strain, which can wear them out and increase their risk of injury. Furthermore, the already taxing demands are made worse by failing to adjust load and speed in response to gradient variations.

According to Al-Khabbaz et al. (2008), carrying a backpack equivalent to 20% of an individual's body weight did not raise the muscular responses when the subjects were merely standing. The integrated sEMG data of the Gastrocnemius Medialis and Vastus lateralis muscles was significantly higher in the female hikers, according to Simpson et al. (2011), when they were walking over 8 km with a rucksack that accounted for 20–40% of their BW. The current research noticed that the lowest response of the RES and LES muscle activities occurred at -20% gradient for all the loads. The highest muscle activity was found at +20% gradient (250% increase in activity compared to 0% gradient and carrying 21.4kg load). In comparison to an unloaded state, the Erector spinae muscle activity during carrying load on incremental gradients and decremental downhill gradients may be related to postural adjustment. According to the study by Harman et al. (2000), the trunk leaned forward to maintain the center of mass over the feet as the amount of the load increased. Nevertheless, this postural adjustment was unable to move the center of mass to the position that was seen when the subject was unloaded.

Thus, the torque around the lower back area may rise owing to the increasing intensity of load and the trunk's forward inclination. This torque may have been counterbalanced by the torque produced by the ES muscles, increasing the muscular activity (Harman et al., 2000). Therefore, it may be considered that walking at an incline increases the effort placed on the ES muscles during weight carriage, and to some extent, walking downhill does too. It is well known that the participants had to lean forward to shift their center of gravity back over the base of support when the load, particularly in the backpack increased and as the intensity increases, individuals change their gait to support the load and recruit more motor units and muscle groups (Pascoe et al., 1997).

The function of VM is to facilitate leg extension. The current study's increased activation of this muscle may suggest that knee flexion is being managed to maintain lower limb stability and compensate for the added load when walking up and down hills. The observations of the VM muscles bilaterally, revealed that -5% was the nadir and at -20% gradient the highest muscle activity was found. At -20% gradient there was an average increase of 284% when normalized to the 0% gradient while carrying 21.4 kg load. Therefore, it was observed that the VM muscles were affected more during downhill walking compared to the uphill walking. The results of this study showed that when it came to leg muscles, the muscles around the knee, including the VM, bore a greater portion of the load when climbing steep hills.

According to research by Chaffin et al. (2006), the pelvis and the lumber spine work together to shorten the distance between the front of the ribs and the pelvis when an individual flexes with a trunk forward lean. This causes the spine to arch. Because of the shift in the center of gravity, the body adopts a more forward posture when the load is positioned at the back, which applies abnormal forces to the spine. When individuals carried a loaded backpack, Goh et al. (1998) reported that stability maintenance and an efficient forward progression led to enhanced lumbosacral forces. It is believed that increased loading of the lower extremity joints, particularly the knee joint, is the main source of injuries and pain experienced by walking downhill (Schwameder et al., 1999). It is well recognized that more muscle electrical activity generation results in higher force production, which raises the risk of injuries and fatigue. The effects of treadmill walking at 0%, 5%, and 10% gradients on a group of individuals were investigated by Silder et al. (2012) for a total of 15 minutes. Similar to the observation of the present study, they too noticed a considerable rise in the VM muscle activity with increasing uphill gradients. However, study participants walked 60 minutes with loads up the gradient for an additional 15% and 20%. The analyzed muscle groups activation patterns although was similar, but the magnitude of the response was significantly greater than that of Silder et al (2012). This implies that the functions of the biarticulate vastus medialis are very important at higher gradients as was also reported by Liu et al. (2020). Consequently, it was shown that walking downhill had a greater effect on the VM muscles than walking uphill. According to research, running downhill causes the knee extensors to flex simultaneously and actively strain more than level running does (Eston et al., 1995). The gradation of active strain on a contracting muscle during a downhill walk is independent of the muscle's relative force exerted and results in the typical signs and symptoms of muscle injury (Leiber and Friden, 1993). According to Chen et al. (2007), the quadriceps femoris muscle should stretch and contract more during downhill running than it does during level ground jogging. According to Lin et al. (2009), the individuals' knee extensor range of contraction and lengthening increased with the steeper the downhill slope they ran on.

According to Reynolds et al. (1990), the ability of a soldier to fight and ultimately the effectiveness of the mission are negatively impacted when they become worn out or injured. The current study's goal was to ascertain how walking at incremental and decremental gradients affected the pattern of activation of the back and leg muscles when carrying varying magnitudes of loads. During walking continuously at both the uphill and downhill gradients, the interaction effects of load-gradient were not significant for all the muscular responses documented in the current study. This study had observed that in the present exercise protocol with loads and uphill gradients, the ES and VM muscles and that for downhill walking the VM muscles of the participants exhibited overexertion and fatiguing responses which may cause injury to these muscles. Research on the process underlying injuries to the muscles, tendons, and ligaments is quite lacking. It can be further reiterated from the observations of Fouad et al. (2001) that the military personnel who took part in this study were all active men. The participants were involved at least for 2-4 hrs per day in sports-related activities which might have contributed to the upregulation of the associated muscular activities as an adaptor response to the higher load and gradient for adjusting to posture and walking.

Previous studies have shown that acute physical activity raises cortisol levels in the saliva, with the degree and duration of the activity influencing this relationship (Jacks et al., 2002). However, from the perspective of military combat performance, salivary cortisol concentration testing is rarely used to predict the strain of carrying varied magnitude of loads at varying walking paces. The current study showed that in a specified uphill-downhill gradient walk routine, cortisol secretion got raised as the quantity of load increased. It seemed that combinations of different load magnitudes and gradients led to relatively higher exercise intensities, which were adequate to raise the cortisol level. This finding aligns with previous research conducted by Hackney et al. (1995). As the participants walked at a speed of 3 kmhr^{-1}, the cortisol concentration raised to around 22%, 42%, and 77% when walking unloaded and carrying 10.7 kg and 21.4 kg, respectively. In the continuous uphill-downhill walk investigation, the post-exercise cortisol concentration increased considerably for each trial as compared to the pre-exercise concentration. Numerous factors, including intense physical activity that stimulates and increases HPA axis activity, elevated body temperature, blood pH changes, hypoxia, accumulation of lactate, and mental stress, may be responsible for this post-exercise upsurge in cortisol levels (Fialire et al., 1996; Lac et al., 1997).

Conclusion

The present research suggests that walking while carrying a load at different uphill and downhill gradients could be stressful to the muscles and higher physical stress from carrying load at various gradient combinations may have contributed to the raised cortisol levels. When Indian military personnel participate in similar exercises during routine military operations at higher altitudes, the hypoxic environment that exists there may exacerbate and quicken the danger of muscular injuries, which could have a significant negative impact on the personnel's combat fitness and morbidity. Consequently, in order to prevent or lessen the extent of muscle damage, military personnel should incorporate into their training regimens a distinct and targeted program of exercises for various muscles recruited during uphill and downhill walking. This is because prior exposure to these scenarios may cause adaptation in the muscles and may protect the muscle from damage or the extent of damage may be diminished.

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