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Injuries, Medical Conditions, and Changes in Blood Levels in German Special Operations Forces Selection

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ABSTRACT

Background: Medical conditions often develop during military training. The aim of this study was to compile medical conditions and injuries sustained during a 5-day military exercise, compare them with incidences at similar civilian events, and subsequently identify differences between those who finished the exercise (Finishers) and those who did not (Nonfinishers) to identify preventable causes for not finishing and to reduce unnecessary health risks. **Methods:** Fifty-one soldiers had their blood parameters (creatine kinase [CK], aspartate transaminase [AST], alanine transaminase [ALT], gamma-glutamyl transferase [GGT], C-reactive protein [CRP], leukocytes, sodium), weight loss, and body temperature determined after the exercise. Additionally, the injuries and conditions that led the Nonfinishers to drop out were recorded. **Results:** The main reasons why Nonfinishers did not complete the exercise were physical exhaustion and minor injuries. After exercise, the Finishers showed only slightly increased incidence of hyponatremia, higher levels of CK, and significantly higher levels of AST, ALT, and CRP, and body weight loss. The Nonfinishers' results were significant for an elevated leukocyte count and lower mean temperatures. **Conclusion:** The specifics of military training did not influence the kind or the number of exertion-related medical conditions compared to similar civilian events. Both Finishers and Nonfinishers are at risk of developing exertion-related medical conditions such as rhabdomyolysis and hyponatremia. However, plain water did not increase the risk of exertional hyponatremia. Leukocytosis found in the Nonfinisher group could have been due to acute excessive exertion and, therefore, may be an indicator of general systemic fatigue. This could be used to differ between physical and psychological reasons for not finishing.

Keywords: *blood test; endurance; military; rhabdomyolysis, exertional; hyponatremia, exertional; strain, physical; injuries; body temperature; selection*

Introduction

A review of the medical literature shows that medical conditions caused by prolonged exertion, some of which may result in death, occur frequently in both the civilian and the military sector.[1–7] While prolonged exertion is undertaken voluntarily in the civilian sector and the responsibility for doing so lies solely with the athletes, members of the military sector, especially those within the Special Operations Forces (SOF), are obligated by nature of their profession. Physical exertion in the Armed Forces is an accepted and essential requirement in training and mission accomplishment. The overall responsibility for its military members, which includes the medical risk due to physical exertion, is shouldered by their superiors. To assist commanders and superiors in minimizing unnecessary casualties and to ensure optimum training and mission execution, the risks of physical exertion to the soldier must be better identified and, subsequently, mitigation strategies developed and implemented.

The aim of this study was to identify the frequency and intensity of injuries and exertion-related medical conditions during a military combat survival exercise performed by the German Army SOF and to compare the results with the frequency and intensity of injuries and exertion-related medical conditions in similar civilian events. This study also examined how the frequency and severity of exertion-related conditions differed among those who finished the exercise (Finishers) and those who did not (Nonfinishers) to identify contributory medical causes. The data was evaluated to aid the optimization of medical care for the patterns of injuries and medical conditions that might be sustained or developed during the course of extreme physical exertion, as experienced in military training and missions.

Methods

The Ethics Committee of the Medical Association of Baden-Württemberg approved the publication of anonymized data.

In March 2012, 51 male soldiers aged between 22 and 33 years (mean age: 26.3 years) participated in a 5-day military combat survival exercise as part of the aptitude assessment procedure for SOF. To participate in the exercise, the soldiers had to complete and pass an ergometry stress test (with a minimum of 3W/kg of body weight), the Bundeswehr Standard Sport Tests, a psychological assessment, and a 10-week special training program. During the exercise, the soldiers had to cover a distance of approximately 160km over hilly terrain while carrying equipment weighing approximately 30kg. Individuals moved as a member of a small team, with each team having to carry a crate of additional equipment weighing approximately 25kg. The exercise was designed as an orientation march, and the teams were tasked to find their own routes between checkpoints. For safety reasons, each team was accompanied by an instructor. The march was frequently interrupted so that special tasks could be performed. These tasks, lasting about 30 minutes, were executed at a maximum level of physical exertion. Breaks of about 6 hours were taken in the afternoon and, during this time, the soldiers had to set up camp before they could sleep. In addition to the physical exertion, the soldiers had to make do with a reduced food supply and with drinking just water, but were allowed to drink as much as they wanted. In summary, the test was a 5-day endurance test involving marching with additional carried weights, sleep deprivation, a reduced food supply, and short periods of maximum exertion.

Before starting the exercise, all participants' body weights were measured and the participants were examined by a physician to identify any medical conditions disqualifying their participation. During the course of the exercise, the Nonfinishers had their blood and temperature taken (tympanic measurement using a Braun ThermoScan®; Braun GmbH; www.brauntherms.com) in a warm environment immediately after dropping out, while the Finishers had their blood and temperature taken at the finish. Within 4 hours, the blood was delivered to the laboratory of a local civilian hospital for processing. The following blood levels were evaluated statistically: sodium, gamma-glutamyltransferase (GGT), alanine transaminase (ALT), aspartate transaminase (AST), creatine kinase (CK), C-reactive protein (CRP), and leukocytes. Other data recorded were the soldiers' current medical conditions, any injuries they sustained during the exercise, and their body weights, which were measured using the same scales during the pre-exercise intake.

The participants were divided into two groups, Finishers and Nonfinishers, and the data were tested for normal distribution using the Shapiro-Wilk test. For the data that were normally distributed, a *t*-test was conducted to compare the groups. For the data that were not normally distributed, comparison was made using the Mann-Whitney *U* test (SPSS Statistics version 20 software; IBM Deutschland GmbH; www.ibm.com/de/de). In each case, the significance level was set at $p \leq .05$. In addition, a purely descriptive comparison with published data from extreme endurance exercises during civilian events was carried out.

Results

Of the 51 participants, 22 completed the exercise (43.1% Finishers). The blood levels of 46 soldiers were analyzed (90.2%). The serum collection tube of one soldier did not contain enough blood for analysis and four other soldiers refused to have their blood taken. The Nonfinishers endured physical exertion for an average of 2.5 days, the Finishers for an average of 5 days.

Hyponatremia

Mild hyponatremia was defined as a sodium level of 135mmol/L or lower. Hyponatremia was considered severe for sodium levels of 130mmol/L or lower and critical for sodium levels of 120mmol/L or lower.[8] Three soldiers (5.9%) were diagnosed with mild hyponatremia (two Finishers (134mmol/L and 135mmol/L) and one Nonfinisher (133.2mmol/L). No cases of severe or even critical hyponatremia were detected. There was no significant difference in the sodium concentration between the Finishers (mean ± standard deviation [SD]: 138.3mmol/L ± 2.1mmol/L) and the Nonfinishers (mean ± SD: 139.4mmol/L ± 2.1mmol/L).

Muscle Damage

Both groups showed a marked increase in both AST and ALT compared to normal reference levels, with the Finishers showing the highest levels. In contrast, none of the participants showed an increase in GGT above the normal level. A marked increase in CK was found in both groups without significant difference between the groups (Table 1). A CK level of 5,000U/L is evidence of serious muscle damage[9]; six of the Finishers and two

Table 1 *Markers of Muscle Damage*

	AST,*,† U/L (ref.: 0–50 U/L)	ALT,*,† U/L (ref.: 10–50 U/L)	GGT,* U/L (ref.: 10–60 U/L)	CK,* U/L (ref.: <190 U/L)
Finishers	149 (44/349)	107 (50/215)	18 (3/37)	3,330 (76/7,850)
Nonfinishers	96 (33/542)	47 (22/292)	18.5 (10/36)	3,020 (348/12,400)

Notes: ALT, alanine aminotransaminase; AST, aspartate aminotransaminase; CK, creatine kinase; GGT, gamma-glutamyltransferase; ref., reference.
*Data given as median (minimum/maximum).
†Significant difference between Finishers and Nonfinishers ($p \leq .05$).

of the Nonfinishers showed serious muscle damage. The two highest levels were detected in the Nonfinisher group (8,150U/L and 12,400U/L).

Markers of General Physical Exertion

The leukocyte count and CRP levels, both inflammation markers, as well as the relative loss of body weight were defined as surrogate parameters to show the effects of general stress on the body (Table 2). While participants in both groups lost weight, weight loss was significantly greater in the Finisher group than in the Nonfinisher group. The Nonfinishers had borderline elevated CRP levels, while the Finishers had significant increase in CRP levels compared to the Nonfinishers. In contrast, the Finishers only had mild leukocytosis, while the Nonfinishers had a significantly elevated leukocyte count compared to Finishers.

Table 2 *Markers of General Physical Exertion*

	Loss of Body Weight*,† kg	CRP*,† mg/dL (ref.: <0.5 mg/dL)	Leukocytes*,† G/L (ref.: 4–10 G/L)
Finishers	−7.8 ± 2.4	1.09 ± 1.31	9.2 ± 2.7
Nonfinishers	−2.4 ± 2.6	0.47 ± 0.42	11.3 ± 2.6

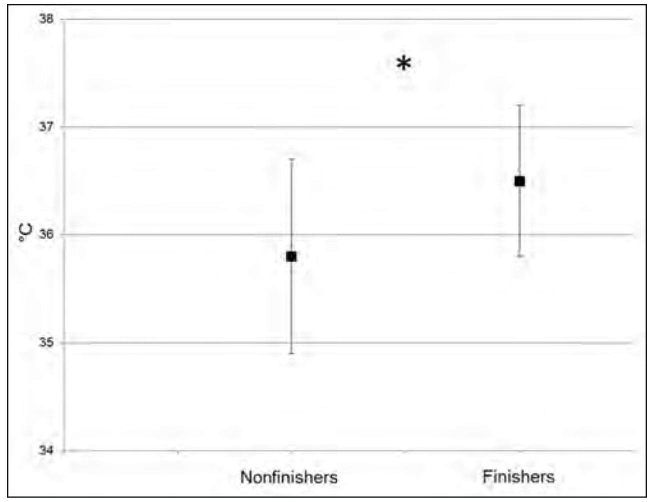
Notes: CRP, C-reactive protein; ref., reference; SD, standard deviation.
*Data given as mean ± SD.
†Significant difference between Finishers and Nonfinishers ($p \leq .05$).

Temperature

Air temperatures in the exercise area ranged from −1°C (30.2°F) to 18°C (64.4°F) during the exercise period, with no precipitation and 8 to 10 hours of sunshine per day. A body temperature of 35°C (95°F) was defined as the threshold for hypothermia, higher than 38°C (100.4°F)[10,11] for hyperthermia, and higher than 40°C (104°F) with additional neurologic symptoms for heat stroke.[4,5]

The body temperatures of 13 Nonfinishers and 21 Finishers were measured, whereas the medical staff did not take the tympanic temperature of 17 soldiers (33.3%) due to a cold environment. Hypothermia was only detected in the Nonfinisher group (34.1°C [93.4°F], 34.6°C [94.3°F], and 34.7°C [94.5°F]), with one soldier showing symptoms of the condition (34.6°C [94.3°F]). A hyperthermic temperature was only measured in one soldier in the Finisher group (38.1°C [100.6°F]), but the soldier did not show any of the clinical signs associated with hyperthermia. Mean body temperatures in the Nonfinisher group were significantly lower than in the Finisher group (Figure 1).

Figure 1 *Mean body temperature of Nonfinishers and Finishers.*



Notes: *Significant difference between Finishers and Nonfinishers ($p \leq .05$).
Bars represent standard deviation. ■, mean data point.

Reasons for Soldiers Not Finishing the Exercise

Table 3 lists the reasons for soldiers not finishing the exercise. It was possible to identify a specific reason for 27 of the 29 Nonfinishers dropping out. No definitive reason for dropping out could be identified for two soldiers, as their documentation forms could not be filled in adequately during the exercise. What can be said, however, is that they did not drop out for medical reasons necessitating hospitalization. The injuries that four soldiers sustained were minor injuries to the musculoskeletal system (ankle sprain, foot contusion, preexisting and acutely exacerbated irritation of the extensor tendons of the foot, cervicalgia) and did not necessitate hospitalization. Medical illnesses that caused participants to drop out were vomiting and exercise-associated postural hypotension, though none of them necessitated hospitalization. The instructors accompanying the teams withdrew 14 soldiers because they could no longer keep up with their teams or perform the additional tasks. The soldier who showed clinical signs of hypothermia quit voluntarily before he was examined by medical staff, which is why it is not listed as a medical reason for dropping out.

Table 3 *Reasons for Soldiers Not Finishing the Exercise*

Reason for Participants Not Finishing	Frequency, No.
Injury	4
Unknown	2
Quitting voluntarily	7
Internal illness	2
Too slow for the team	14
Total	**29**

Discussion

The exercise involved the typical exertion experienced by soldiers while marching and carrying personal equipment for long periods of time, though it was made more severe by limiting the supply of food. The intensity of the exercise and additional induced deprivations considerably exceeded those of routine military duty. This means that the physical disorders listed can be expected to be less frequent and severe in shorter and less intense military endurance exercises.

Hyponatremia

The hyponatremia incidence of 5.9% in this study was low, on the whole, and the condition was not very pronounced in terms of intensity. No statistical difference could be found between Finishers and Nonfinishers. Electrolyte imbalance in the form of exercise-induced hyponatremia, therefore, was not a reason for anyone participating in the exercise to drop out.

The incidence we detected in our study was lower than the incidence in comparable, extreme long-term endurance exercises (e.g., Ironman) and mass events such as marathons, which show incidences of 13% to 30% for hyponatremia.[7,8,12,13] It seems that among the participants in this exercise, consuming pure water with a sodium concentration of approximately 20mmol/L[14] did not increase the risk of developing hyponatremia. Therefore, our data imply that no special electrolyte drinks are necessary to prevent exertional hyponatremia. This finding is supported by Almond et al.,[8] who did not find any correlation between hyponatremia and the type of liquid consumed[8], whereas there is evidence that sodium-free liquids increase the risk of hyponatremia.[15] In view of the fact that common sports drinks have an average sodium concentration of 18mmol/L, which is less than one-fifth of the normal physiologic sodium concentration, it seems that the sodium concentration of the consumed liquid is of considerably less importance than commonly assumed.[7,8] What is relevant is the amount of liquid consumed, since most authors consider water intoxication to cause hyponatremia.[6–8] This means that the condition may develop at any time, especially in soldiers who drink at predefined intervals and not when they are thirsty.[8]

Muscle Damage

Significantly elevated CK, ALT, and AST levels were detected in both groups as evidence of muscle tissue damage, with ALT and AST levels significantly higher among the Finishers and average CK concentration only slightly elevated. The longer average period of exertion can account for this. Liver damage could be ruled out as a cause for the release of ALT and AST, as the soldiers had normal GGT levels.

In cases of acute necrosis of muscle cells (rhabdomyolysis), the CK level is the most sensitive marker for determining the extent of tissue breakdown. This condition can have potentially life-threatening complications such as acute renal failure or hyperkalemia but can also be asymptomatic.[16,17] One problem is that severe physical exertion often leads to a systemic rise in CK levels as a correlate of muscle damage.[1,18–21] The level above which this leads to serious complications and must be treated cannot, however, be clearly defined.[16,17] It is emphasized in studies that neither the presence nor the extent of elevated CK levels in cases of exertion-induced rhabdomyolysis allows any predictions to be made with regard to acute renal failure.[1] Clarkson et al.[18] did not find any evidence of renal disorders in healthy young volunteers with exertion-induced rhabdomyolysis and CK levels of sometimes more than 10,000U/L. In most clinical case reports on complicated rhabdomyolysis, CK levels consist of five figures.[1,16,17] Some authors also recommend that patients who solely have CK levels up to 15,000U/L and no other risk factors be treated as outpatients under close supervision.[22] This all implies that a marked elevation of CK levels alone need not be considered an illness requiring treatment, but rather a normal correlate of extreme physical exertion. None of our soldiers suffered from hyperkalemia or continuous oliguria, so we can assume that any rhabdomyolysis did not involve complications and rhabdomyolysis has not been listed as a reason for dropping out. However, it must be emphasized that medical personnel must always be aware of the complications that may develop both in the Finisher group (higher average CK concentration) and the Nonfinisher group (higher maximum levels).

Extreme CK elevations have also been observed during civilian events involving extreme physical exertion. Examples are average levels of more than 15,000U/L during a 24-hour race and almost 40,000U/L in 20% of a random group of participants during a race of 161km.[1,21] However, even during mass sporting events such as marathons, considerable CK elevations with mean levels of 2,470U/L are frequently detected the day after the event,[23] which means that the levels detected in our groups need not be considered excessive.

Systemic Physical Exertion

A comparison of the two groups showed that the Finishers had significantly elevated CRP levels and a significant loss of body weight, whereas the Nonfinishers had a significantly elevated leukocyte count (Table 2).

Exertion-induced systemic reaction or fatigue is difficult to represent in objective measurements. However, in addition to the CK elevation discussed, which correlates with the distance covered by the soldiers,[21] loss of body weight and the systemic inflammatory response set off by exertion-induced cell damage[20,21] can be used to assess overall physical exertion.[19] The elevated CRP levels and the greater loss of body weight among the soldiers who finished the exercise can be accounted for by their higher total exertion. The fact that the Nonfinishers had significantly higher leukocyte counts despite experiencing less total exertion suggests that this might not have been caused by the total level of exertion, but by an exertion peak. In most studies we looked at, blood parameters were determined at the end of a period of exertion. No studies were identified where the focus was on Nonfinishers. However, there are studies that show physical exertion above the anaerobic threshold is accompanied by more severe leukocytosis and immune modulation than physical exertion below the anaerobic threshold.[24] The results of our measurements of the total leukocyte count, therefore, suggest a state of acute excessive stress in the Nonfinishers. It is thus plausible that measuring a soldier's leukocyte count at the time of dropping out of the exercise may help differentiate whether quitting the exercise would be due to total systemic fatigue or any of many other reasons.

Studies of the immune response during Ironman triathlons and 24-hour races showed CRP elevations up to levels of 3.9mg/dL and leukocytosis up to a mean level of 20G/L.[20,21] The levels we measured are below those described in these studies.

Temperature

The temperature screening we carried out did not produce any indication of conditions or deficiencies induced by hyperthermia. In particular, there was no indication of exertional heat stroke that was either clinical or based on temperature measurements. However, the accuracy of tympanic temperature measurement is a controversial issue.[25] In general, the tympanic temperature measured without the influence of cold water and at moderate ambient temperatures (between 12°C [53.6°F] and 34°C [93.2]) differs from the body's core temperature by 0.6°C (33°F) to 1.7°C (35°F).[25,26] On the whole, tympanic temperature measurement is fast and uncomplicated, and patients are significantly more willing to have their temperature taken using this method rather than the more accurate rectal temperature measurement. The tympanic temperature measurement is sufficiently accurate for general data collection, such as encountered in our setting.[25]

Under the climatic conditions that prevailed during our observation period, mild hypothermic body temperature shifts (32°C [89.6°F] to 35°C [95°F]) were more frequent in the Nonfinisher group. One soldier showed corresponding symptoms (at 34.6°C [94.3°F]): he felt very cold and was shivering, and was treated with hot drinks and optimization of insulation. A decrease in the core body temperature is generally associated with physical impairment.[10,11] Physical exhaustion, sleep deprivation, and a negative energy balance also foster the development of hypothermia.[27] Therefore, hypothermia on the one hand and physical and cognitive impairment on the other have a negative amplifying effect on each other. This means that hypothermia increases the likelihood of soldiers dropping out because of impairment, while the reverse conclusion is that there is an increased risk of exhausted soldiers developing hypothermia. In our group, this was evidenced by the significantly lower body temperatures among the Nonfinishers. It is thus important to carry out consistent and thorough hypothermia prophylaxis from the very start of the exercise onwards.

As a rule, the occurrence of thermoregulatory dysfunctions depends strongly on the climatic conditions. During 1-day mass sporting events under similar climatic conditions, hypothermia requiring treatment was detected in 1.4% of all participants.[25] This frequency corresponding to that measured in our group.

Medical Reasons for Soldiers Not Finishing the Exercise

A total of six participants did not finish the exercise for medical reasons. There are few data on the types of injuries that are sustained and medical conditions that develop during military exercises. In Naval Special Warfare training, the frequency at which injuries are sustained in basic training is up to 30% per month, which, after the adjustment of the person-days, corresponds more or less to the frequency observed in our study.[28] The aptitude exercise described in this study can be best compared to civilian outdoor competitions. During these events, up to 2% of the participants require medical assistance, which corresponds to a rate of 10% for a 5-day event and approximately to the injury rates we observed in our study.[29]

Injuries sustained during outdoor, adventure, and wilderness activities and competitions mostly come in the form of contusions, sprains, and skin lesions, just as we have seen in our setting.[29,30] In contrast, fractures and dislocations are less common and all the injuries can generally be classified as being less severe.[29–31] Approximately 20% of the cases involve exacerbated old injuries, as we saw in one Nonfinisher. This emphasizes the importance of participants undergoing a thorough medical examination before taking part in such an event.[30] The most common disorders are gastrointestinal complaints, infections, and acute respiratory diseases. In this study, we observed only one case of vomiting.[30] The types of injuries sustained and conditions developed by our group, and their frequency and severity were comparable to those seen at civilian events.

Pass or Fail

Of the 29 soldiers who did not finish the exercise, seven dropped out of their own accord and 14 were withdrawn by the team leaders because they were slowing the team down (Table 3). This means that those soldiers, who made up 72% of all the Nonfinishers, did not have any distinct medical reason for dropping out.

It is notable that there were larger mean values of the measured parameters in the Finisher group, with the exception of significantly higher leukocytosis in the Nonfinisher group. These levels can probably be accounted for by the fact that the Finishers experienced greater and longer-lasting physical exertion. Since all the soldiers were in similarly good physical condition at the beginning of the exercise (they had successfully completed the training program and passed the ergometry stress test for which the minimum was 3W/kg of body weight), psychological factors such as the capacity for enduring pain, willpower, motivation, and determination seem to play a fundamental role in bearing up against extreme physical exertion. One possible explanation for this is that the psychological profiles of exceptional athletes often differ from those of the average population, and a distinct psychological factor can be assumed to play a role in whether a soldier passes or fails the exercise.[32–34] With regard to medical care, this means that the risk of complications must not be underestimated even for soldiers who might have passed the test. Some experience more severe physical reactions to exertion than soldiers who do not finish the exercise, but are determined to tolerate and deny the physical consequences of the exertion for a longer period of time. The transition range to acute excessive exertion that forces a participant to stop seems to be very narrow, as evidenced by the extreme levels in parameters (CK, hyponatremia, hypothermia) measured in the Nonfinisher group. This is why, irrespective of whether the test is passed, a close watch must be kept for exertion-related complications, particularly in soldiers who are highly motivated and have a high capacity for enduring pain.

Limitations

We did not manage to obtain the complete set of data as planned from all the participants during the exercise. The primary focus was on the exercise and the medical study had to give way at times to ensure a successful exercise. Measurements were only taken once, so no process data are available. It is thus not possible to compare postexercise to preexercise levels or issue any statement on maximum levels. The test data are only snapshots taken at the time when a soldier either dropped out or finished the exercise.

Conclusions

The range of potentially life-threatening injuries and medical conditions requires sound medical support to be ensured and thorough medical examinations to be conducted on the participants before the exercise. Nonfinishers (greater maximal deviation of blood parameters) and Finishers (greater mean deviation of blood parameters) are at risk of developing rare but potentially life-threatening exertion-related medical conditions such as rhabdomyolysis and hyponatremia. Plain water did not increase the risk of exercise-related hyponatremia. Hypothermia prevention should be considered a key factor for success.

The patterns of medical conditions developed and injuries sustained during military exercises do not differ in principle from those at comparable civilian sporting events under the climatic conditions the exercise was conducted. The physical demands commanders request from their troops, therefore, are not likely to pose an exaggerated health risk.

The significantly higher leukocytosis found in the Nonfinisher group could be a sign of acute excessive stress caused by an exertion peak and, therefore, could shed some light on the question of whether acute systemic fatigue or other aspects like psychological reasons caused soldiers to drop out of an exercise. Further research is needed to elucidate this aspect in a more detailed fashion.

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Disclosures

The authors have nothing to disclose.

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