USARIEM TECHNICAL NOTE

DAILY WATER REQUIREMENTS WHEN WEARING BODY ARMOR

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Water is essential for sustaining warfighter performance. The warfighters' daily water requirements increase with work and climatic heat stress. Clothing which increases the energy cost of a specific task and/or increase sweat production will increase the daily water needs of the warfighter. This report presents the results of model simulations predicting the individual daily water requirements under a broad range of energy expenditures and weather conditions when wearing battle dress uniform alone or when wearing battle dress uniform with body armor. The addition of body armor increases the daily water requirement from 0.5 to 2.0 quarts per man per day, with the greatest additional need when work is performed in hot weather and energy expenditures are in excess of 4,000 kilocalories per day.

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Delivery of adequate water to the warfighter is essential for sustaining performance. Recommendations for daily water requirements were developed for soldiers wearing the battle dress uniform (BDU). The modern warfighter, however, wears BDU + body armor rather than BDU alone. The Warrior System Integration Team requested that the daily water requirements be revisited for soldiers wearing both BDU and BDU + body armor under a variety of work levels and weather conditions. This report summarizes the work performed and the results of this effort.

METHODS

The USARIEM Heat Stress Decision Aid (1) was used to estimate hourly sweating rates of soldiers over average daily wet bulb globe temperatures (WBGT) ranging from 10° to 35°C. This model uses the sweating algorithms developed by Shapiro et al. (2) to predict hourly sweating rates. The scenario was run for a 75 kg soldier at rest, and performing work at low (250 W), moderate (425 W) and hard (600 W) work in each weather condition wearing BDU alone and BDU + body armor.

To produce the broad range of weather conditions, dry bulb temperature was varied in an incremental manner while relative humidity was held constant, and globe temperature was adjusted to always be 15°C higher than dry bulb temperature to simulate full sun conditions.

Daily water requirements were calculated by varying the intensity and duration of work for a 12 h period. It was assumed that for the remaining 12 h in the simulation, the soldier would be at rest (90 W). It was also assumed that the soldier had a daily minimum requirement of 1.5 liters to replace water lost in respiration and urine. The 1.5

liters was added to the estimate of daily sweat losses to produce the daily water loss or daily water requirement.

RESULTS

Figures 1-4 present the daily water requirements for soldiers wearing either the BDU alone or BDU + armor and expending ~2700, 3300, 4500 and 5500 kcal per day, respectively. The results presented in Figures 1-4 illustrate that when daily energy expenditure is held constant, body armor has relatively little impact on daily water requirements. During light and moderate work, body armor increases water requirements approximately <0.5 quarts per day. During more prolonged work and energy expenditures of 4500 to 5500 kcal, body armor raised the daily water requirement 0.5-1.0 quarts/day. However, in the "real world," daily energy expenditure would only remain the same with body armor compared to BDU alone if work rate were allowed to decrease, as the added weight of the body armor increases the energy cost of locomotion and all body-weight bearing activities.

To provide an estimate of the daily water requirements when the same activities are performed with BDU + body armor vs. BDU alone, the energy cost of movement was calculated for a 75 kg man with and without body armor (assumptions: 75 kg man, 9 kg vest). Daily energy expenditure was then recalculated based on the new energy requirements. Figures 5-8 present the daily water requirement for a 75 kg individual wearing body armor compared to when wearing only BDU when the same physical activities are performed. Wearing body armor during the ~2,700, 3,300, 4,500, and 5500 kcal scenarios increased the daily caloric cost ~200, 265, 360, and 500 kcal,

respectively. Furthermore, wearing body armor raised the daily water requirement ~0.5, 0.7, 1.4, and 2.0 quarts per day.

Figure 1. The daily water requirements for light physical activity (2650 kcal/day) when wearing BDU or BDU+armor

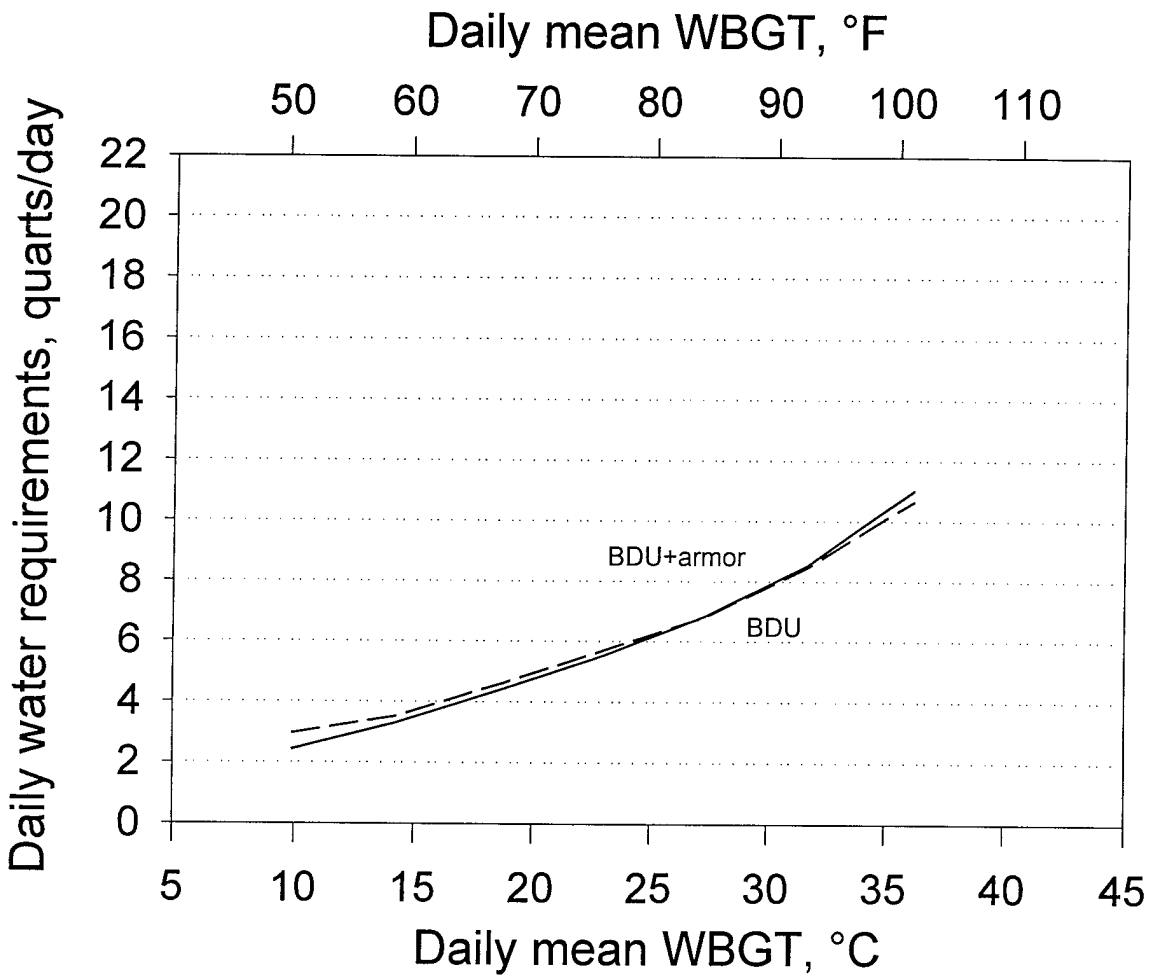


Figure 2. The daily water requirements for moderate physical activity (3325 kcal/day) when wearing BDU or BDU + armor

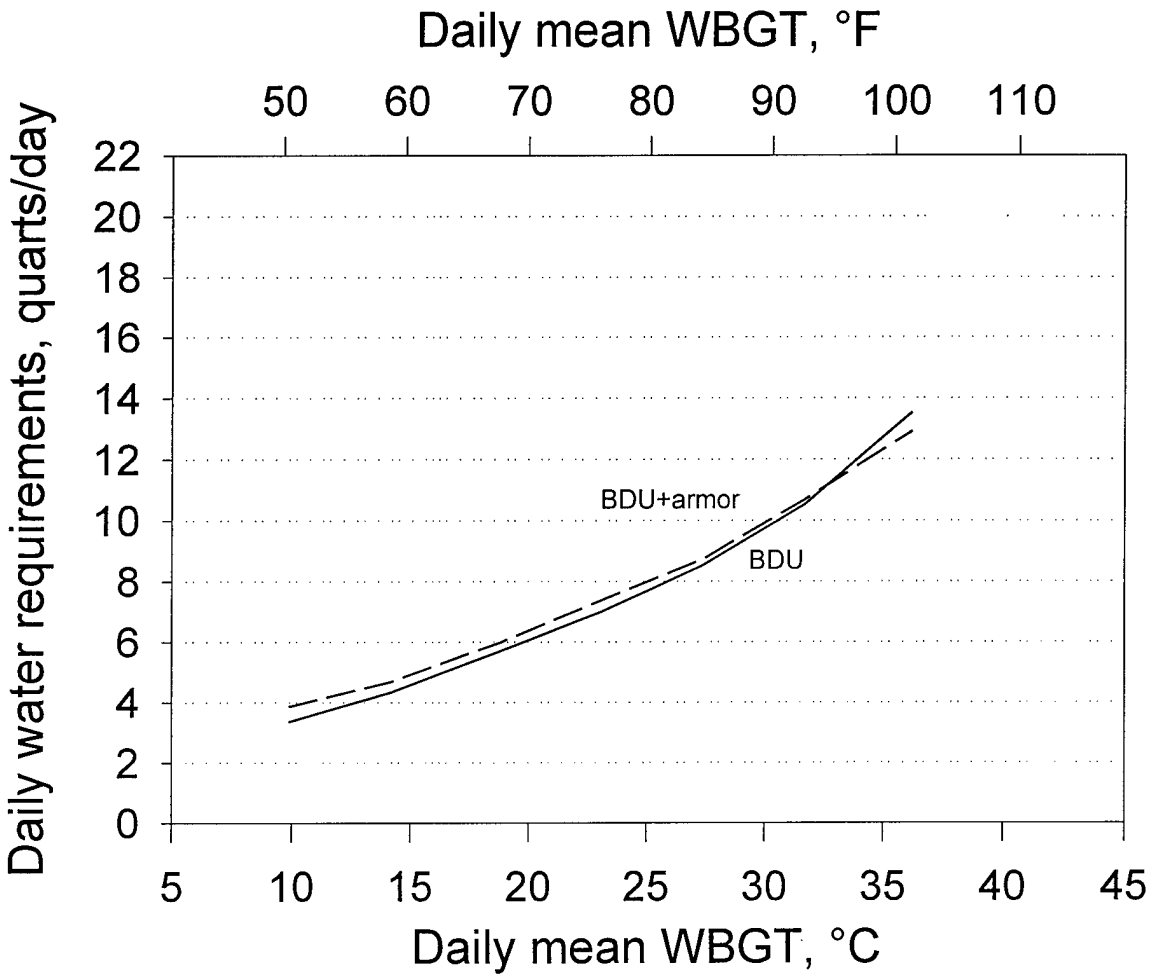


Figure 3. The daily water requirements for moderately hard physical activity (4490 kcal/day) when wearing BDU or BDU+armor

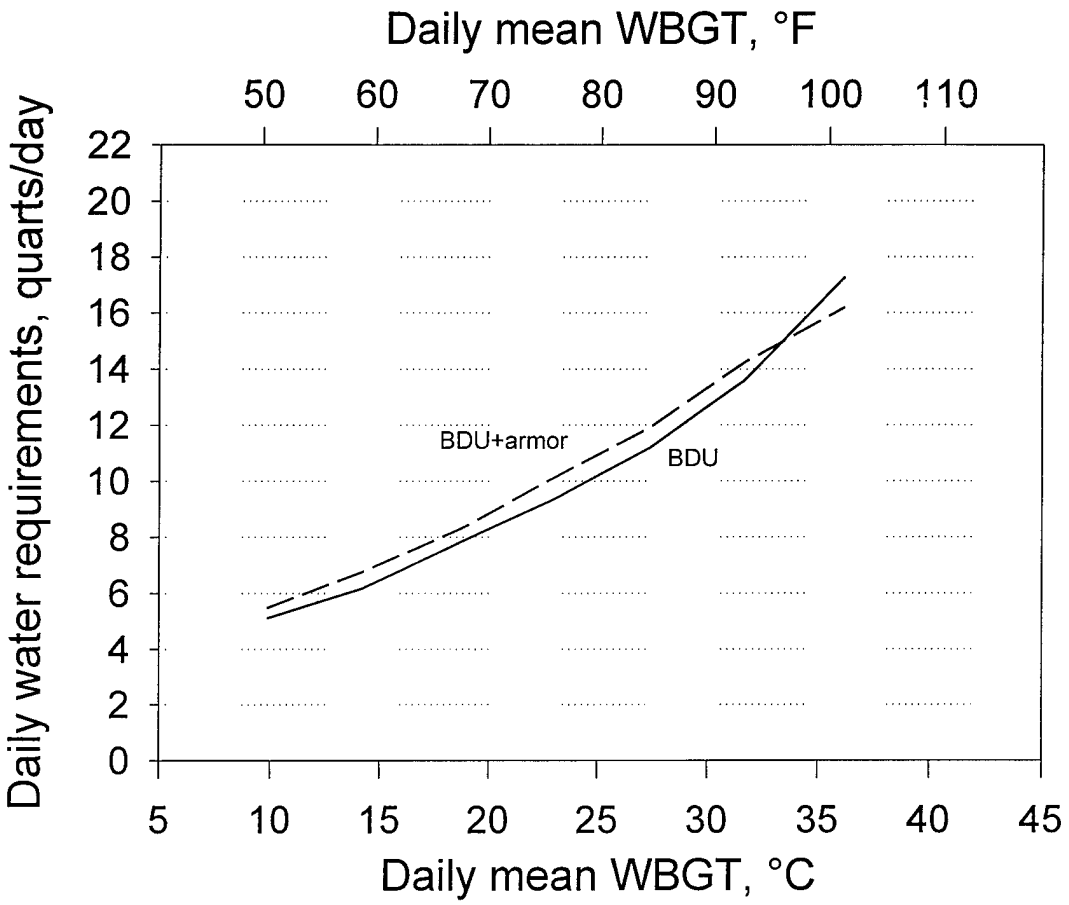


Figure 4. The daily water requirements for hard physical activity (5540 kcal/day) when wearing BDU or BDU+armor

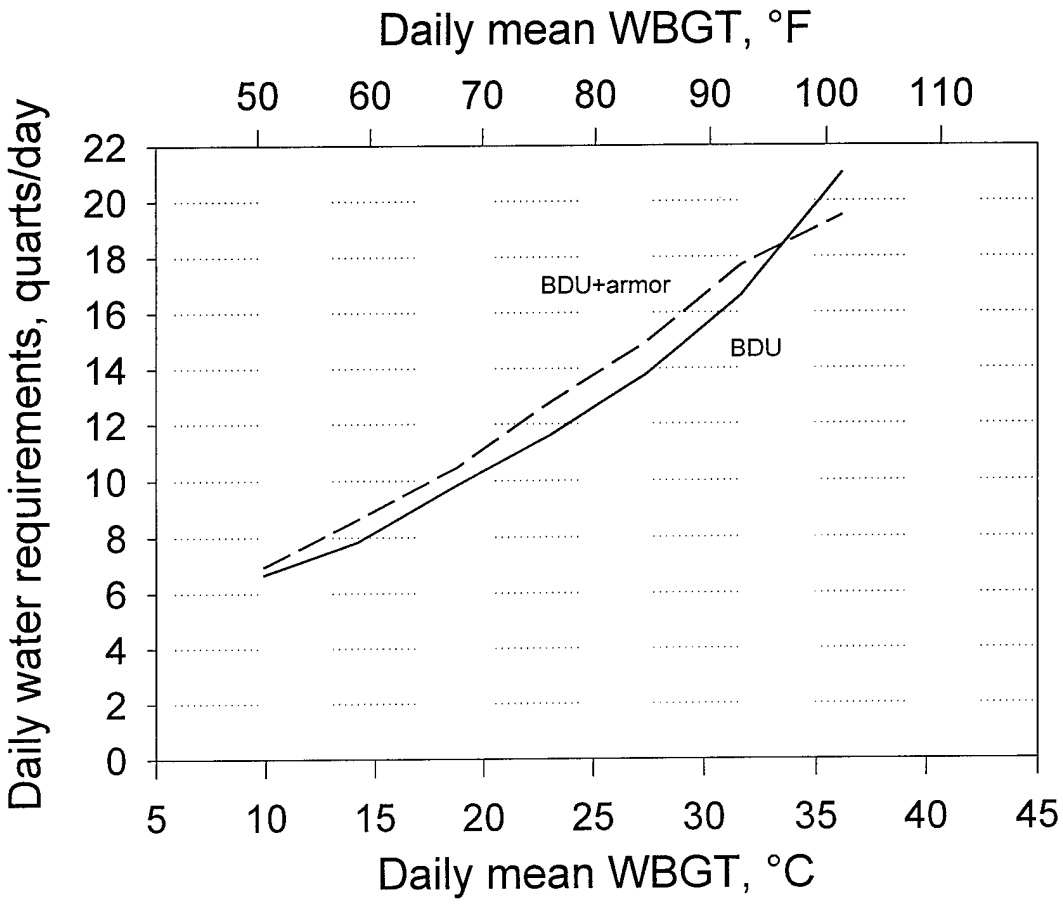


Figure 5. The daily water requirement for light physical activity scenario when wearing BDU alone or BDU+armor. The same tasks were completed with and without addition of body armor

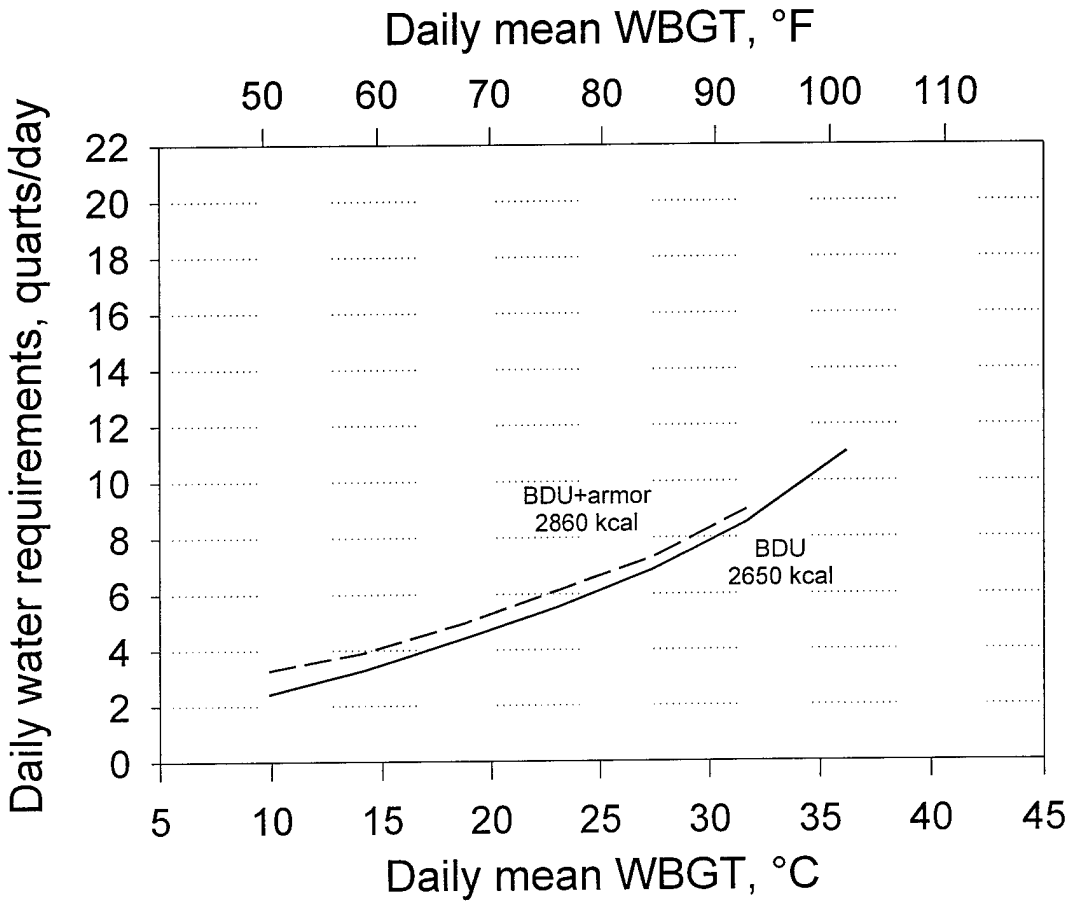


Figure 6. The daily water requirement for moderate physical activity scenario when wearing BDU alone or BDU+armor. The same tasks were completed with and without addition of body armor

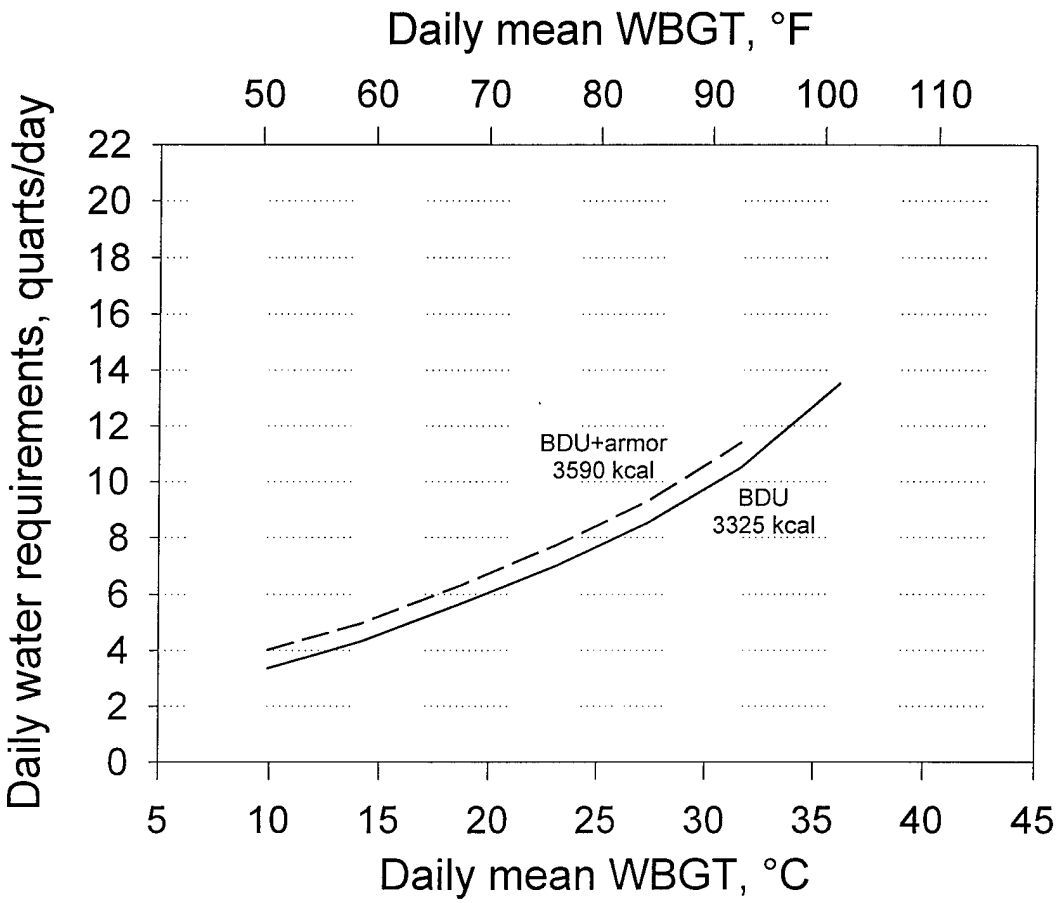


Figure 7. The daily water requirement for moderate-hard physical activity scenario when wearing BDU alone or BDU+armor. The same tasks were completed with and without addition of body armor.

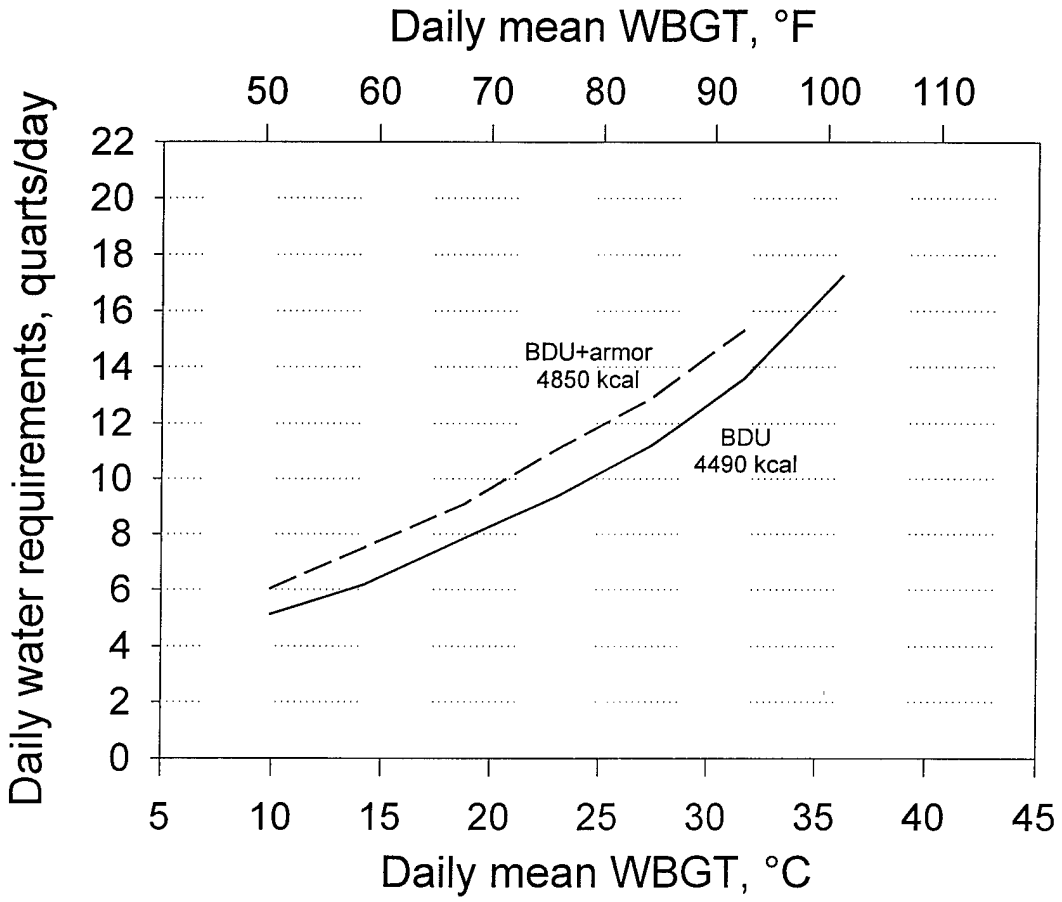
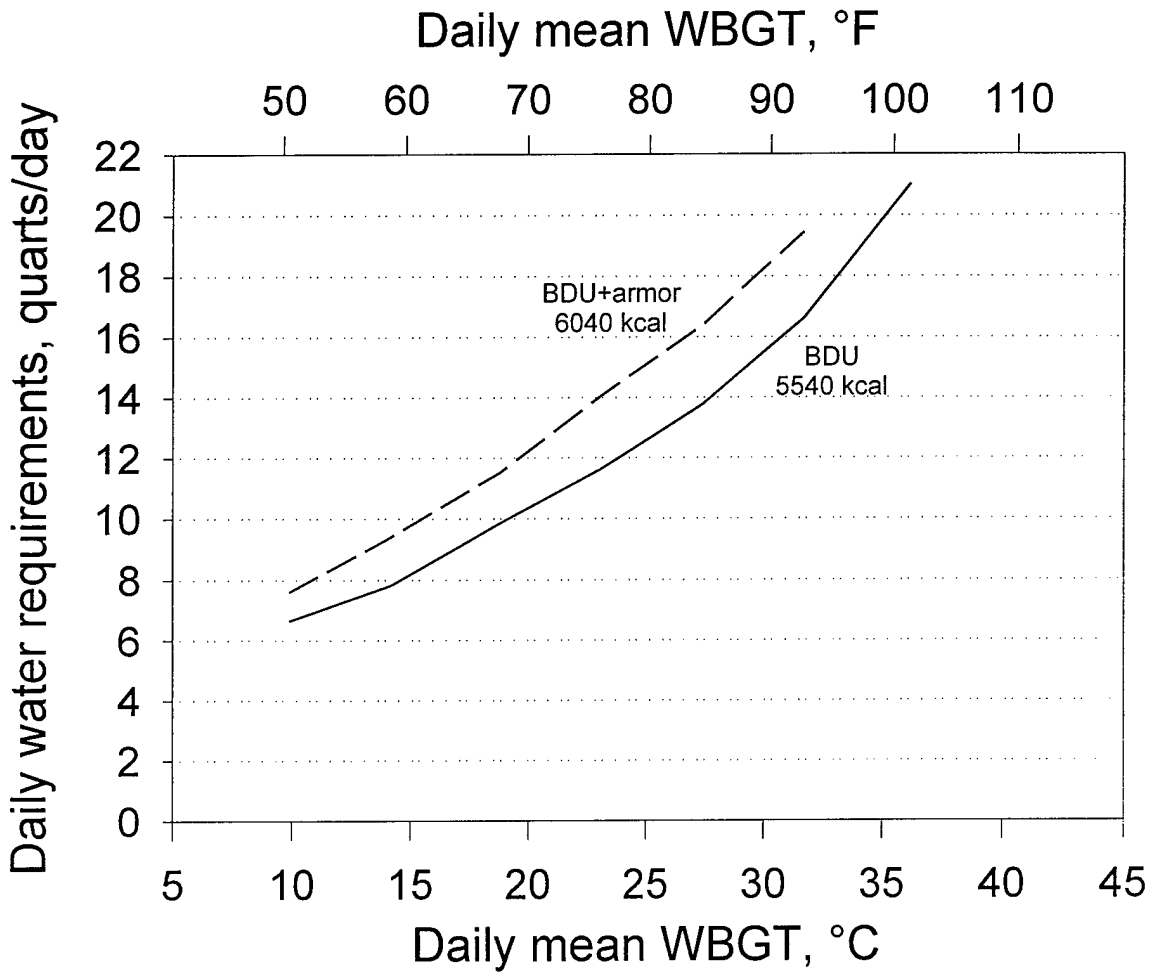


Figure 8. The daily water requirement for hard physical activity scenario when wearing BDU alone or BDU+armor. The same tasks were completed with and without addition of body armor.



DISCUSSION

This report demonstrates that when daily energy cost is similar when wearing BDU or BDU + armor, the addition of body armor has little impact on the daily water requirements of the warfighter. However, when the same activities are performed when wearing body armor compared to no body armor, the armor increases the warfighter's daily water needs an additional 0.5 to 2.0 quarts per day.

There are several limitations to these predictions, and these limitations should be considered before extrapolation to all soldiers and all scenarios:

1. The predictions estimate daily water requirements based on the average daily climatic conditions. If the majority of physical activity is performed during either the cooler or hotter parts of the day, the predictions will overestimate and underestimate, respectively, the actual water requirements.
2. The sweating rates were calculated under full sun conditions. If the work is performed in partial or nighttime conditions, the prediction will modestly overestimate water losses, as less sweat is secreted in non- or partial sun conditions.
3. The estimate of the added energy cost of wearing body armor assumed the soldier weighed 75 kg and that the armor weighed 9 kg. The energy cost of locomotion is proportionate to body mass. Thus, the predicted sweating rates are likely overestimated for smaller individuals and underestimated for larger individuals. Similarly, the added energy cost of locomotion produced by the armor would be greater in a smaller individual and less in a large individual. This means that the armor would increase the daily water need more for a soldier with light body mass compared to someone heavier.

In summary, the daily water requirements of the dismounted warfighter were calculated over a range of weather and activity levels when wearing BDU alone or BDU + body armor. The daily water requirements of the warfighter increased as a function of climatic stress and activity. The addition of body armor added relatively little to the daily

water needs of the warfighter when total daily energy expenditures were similar. However, when the warfighter completed the same tasks when wearing body armor as when wearing only BDU, the daily water requirements were increased an additional 0.5 to 2.0 quarts per person per day.

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