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MODELING COLD STRESS – RUSSIAN SOLDIERS IN UKRAINE

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MODELING COLD STRESS – RUSSIAN SOLDIERS IN UKRAINE

Adam W. Potter
David P. Looney
Karl E. Friedl

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U.S. Army Research Institute of Environmental Medicine
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14. ABSTRACT
Media reports on 14 March 2022 suggested that Russian soldiers bogged down in vehicles, possibly without fuel resupply, were at serious risk for hypothermia and/or surrender in the next 72 hours due to predicted ambient temperatures as low as -20°C near Kyiv. This short report demonstrates the power of predictive thermal models developed by USARIEM to predict relevant operational outcomes within a very short period of time (hours). The results of the modeling did not support the media predictions of hypothermic soldiers although there would likely be some uncomfortably cold conditions. Instead, serious peripheral freezing cold injuries, especially the feet, were predicted as the most likely injury risk. More specific data can produce more accurate predictions. For example, USARIEM has a large database of biophysical properties of various cold weather uniforms from the US, Norway, and Canada. These data were used in this modeling exercise as “similar” uniform systems based on analysis of current media photos of the clothing of captured Russian tank crews.

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EXECUTIVE SUMMARY

Media reports on 14 March 2022 suggested that Russian soldiers bogged down in vehicles, possibly without fuel resupply, were at serious risk for hypothermia and/or surrender in the next 72 hours due to predicted ambient temperatures as low as -20°C near Kyiv. This short report demonstrates the power of predictive thermal models developed by USARIEM to predict relevant operational outcomes within a very short period of time (hours).

The results of the modeling did not support the media predictions of hypothermic soldiers although there would likely be some uncomfortably cold conditions. Instead, serious peripheral freezing cold injuries, especially the feet, were predicted as the most likely injury risk.

More specific data can produce more accurate predictions. For example, USARIEM has a large database of biophysical properties of various cold weather uniforms from the US, Norway, and Canada which were assembled by the former Biophysics and Biomedical Modeling Division. These data were used in this modeling exercise as “similar” uniform systems based on analysis of current media photos of the clothing of captured Russian tank crews. Other assumptions were bounded by best and worst case conditions, such as availability of fuel to run vehicle heating systems, and assumed low physical activity levels.

INTRODUCTION

A recent article raised the potential for Russian soldiers in a stalled 40-mile long convoy to 'freeze to death' while stopped or moving slowly in below freezing temperatures (https://www.independent.co.uk/news/world/europe/russia-troops-convoy-freezing-death-b2031696.html).

The article makes the case that with temperatures dropping below freezing (and potentially as low as -20°C) will pose cold stress on the Russian soldiers to the point of making them leave their vehicles and surrendering to "avoid freezing to death". While this is an optimistic viewpoint, it is worth considering the potential for this type of troop disruption and the associated impact it can have on their movement.

METHODS

Modeling Cold Responses

Mathematical models and artificial intelligence (AI)- based computational methods for predicting human thermal responses are generally used for preventing cold stress injuries (1-2). In this case, these thermal modeling can be leveraged for tactical insights into the health status of opposition forces.

At a minimum, modeling human responses requires inputs from four elements, 1) environmental conditions, 2) the human, 3) their activity level, and 4) clothing properties. For this analysis, we have used USARIEM's existing thermal models (3-5), along with open source estimates of the environmental conditions, made some assumptions regarding the 'typical' Russian soldier and their activity, and based on some observations used comparable clothing values to make predictions.

1) Environmental Conditions

Current open source weather forecasts were used to project conditions for the next 10 days in Kyiv, Ukraine; where estimates ranges for air temperature (Ta) are low of -8°C and highest of 8°C, Relative Humidity from 48 – 78%, and wind velocity 10 – 19 km/h (Weather.com). Our analyses shows a range of best and worst conditions (where 'best' is considered they are most stressed and 'worst' is less stressful and likely uninjured).

2) Clothing Biophysics

Based on observational assessments of Russian cold weather clothing, there are some clothing properties with likely comparable values that can be used to make estimates (6-7). If the Russian military were using their complete (8 layer) cold weather clothing system (Appendix Figure 1), they would be fairly well protected from extreme cold exposure. Elements of most importance would be focused on extremities (hands, feet) and areas of soft tissue (e.g., cheeks). The element less known, and more important in these analyses are gloves and boots. From internet obtained images (Appendix A), it appears that the Russian military may be using these clothing systems to some extent, but not likely the complete sets (specifically using light gloves vs. cold weather mittens, Appendix Figure 2); while the boots from images seem to be light weight (not extreme cold weather boots).

Human Inputs

3) Individual

Simple assumptions can be made of the 'typical' Russian soldier. While information regarding the impact of additional potential physiological stressors (e.g., undernourished, dehydrated, sleep deprived) can be made based, the current analysis considers the 'simulated individual' is a healthy young male. Though it is important to note that these added stressors can have a significant impact on the thermoregulatory effectiveness as well as the added potential for fatigue.

4) Activity level

Base on this analysis, the activity rate was considered as low (representative of sitting in a vehicle) (~116 W) (8-11). It is important to note that with the restricted ability for movement (e.g., in a vehicle such as a tank), the ability to maintain body heat (i.e., metabolic heat production) is significantly reduced.

RESULTS

In Vehicle:

Modeled conditions were conducted for four scenarios with individuals resting/sitting in vehicle (116 W), in two air temperature conditions (Ta -8 and -20°C), with low wind penetration (60%RH and 1 km/hr wind velocity), and with both high (Figures 1-2) and low (Figures 3-4) hand and foot protection.

Outside vehicle:

Modeling was also conducted for six conditions outside at low work rate (137W), in three air temperature conditions (Ta, 5, -8, and -20°C), with exposure to wind (60%RH and 17 km/hr wind velocity); and both high (Figures 5-7) and low (Figures 8-10) hand and foot protection.

Threshold points:

Table 1 shows the predicted times to reach general skin temperatures thresholds for loss of dexterity (~8°C), for pain to begin to occur (~5°C) and frostbite (<1°C) (2,12).

Table 1. Predicted times to reach thresholds within 250 minutes of exposure

	Condition	Body Part	Dexterity /numbness (8°C)	Pain (5°C)	Frostbite (<1°C)	Figure #
In vehicle	Ta -8°C high protection	Exposed skin	<10 min	<10 min	<10 min	1
		Hands/Fingers	N/A	N/A	N/A	
		Feet/Toes	N/A	N/A	N/A	
	Ta -20°C high protection	Exposed skin	<10 min	<10 min	<10 min	2
		Hands/Fingers	N/A	N/A	N/A	
		Feet/Toes	130 min	185 min	N/A	
	Ta -8°C low protection	Exposed skin	<10 min	<10 min	<10 min	3
		Hands/Fingers	N/A	N/A	N/A	
		Feet/Toes	N/A	N/A	N/A	
	Ta -20°C low protection	Exposed skin	<10 min	<10 min	<10 min	4
		Hands/Fingers	205	N/A	N/A	
		Feet/Toes	65	130	N/A	
Outside	Ta 5°C high protection	Exposed skin	<10 min	40 min	N/A	5
		Hands/Fingers	N/A	N/A	N/A	
		Feet/Toes	N/A	N/A	N/A	
	Ta -8°C high protection	Exposed skin	<10 min	<10 min	<10 min	6
		Hands/Fingers	N/A	N/A	N/A	
		Feet/Toes	N/A	N/A	N/A	
	Ta -20°C high protection	Exposed skin	<10 min	<10 min	<10 min	7
		Hands/Fingers	N/A	N/A	N/A	
		Feet/Toes	95 min	130 min	220 min	
	Ta 5°C low protection	Exposed skin	<10 min	<10 min	N/A	8
		Hands/Fingers	N/A	N/A	N/A	
		Feet/Toes	N/A	N/A	N/A	
	Ta -8°C low protection	Exposed skin	<10 min	<10 min	<10 min	9
		Hands/Fingers	N/A	N/A	N/A	
		Feet/Toes	95 min	N/A	N/A	
	Ta -20°C low protection	Exposed skin	<10 min	<10 min	<10 min	10
		Hands/Fingers	65 min	N/A	N/A	
		Feet/Toes	45 min	55 min	75 min	

Figure 1. Clothing: mittens and cold weather boots (similar to Army mittens and VB boots), **Environmental conditions:** In vehicle: Ta -8°C, 60% RH, 1 km/hr wind velocity.

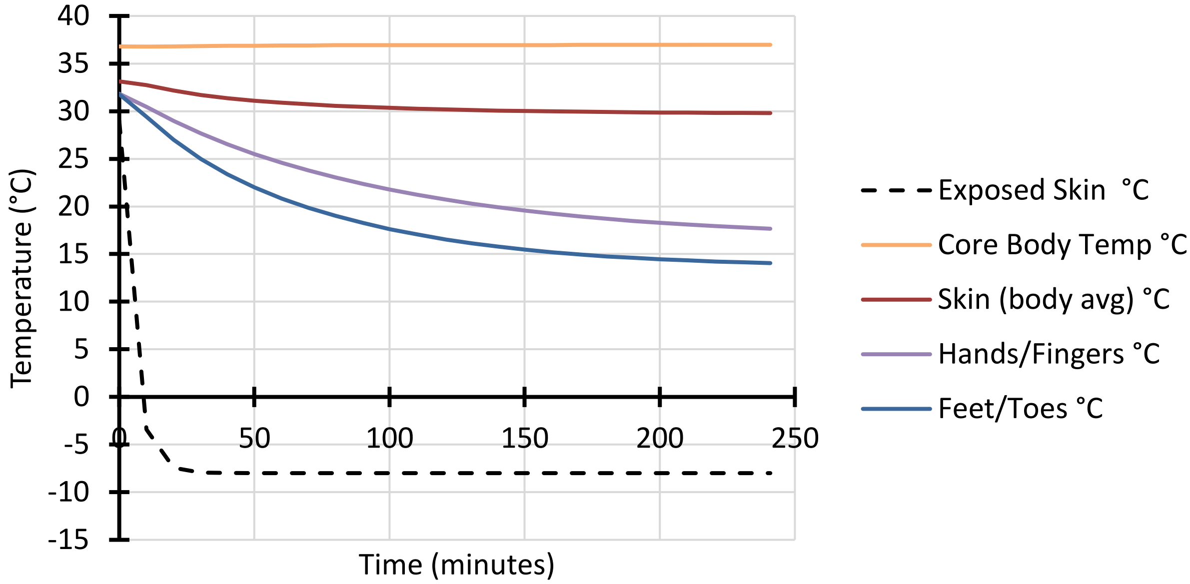


Figure 2. Clothing: mittens and cold weather boots (similar to Army mittens and VB boots), **Environmental conditions:** In vehicle: Ta -20°C, 60% RH, 1 km/hr wind velocity.

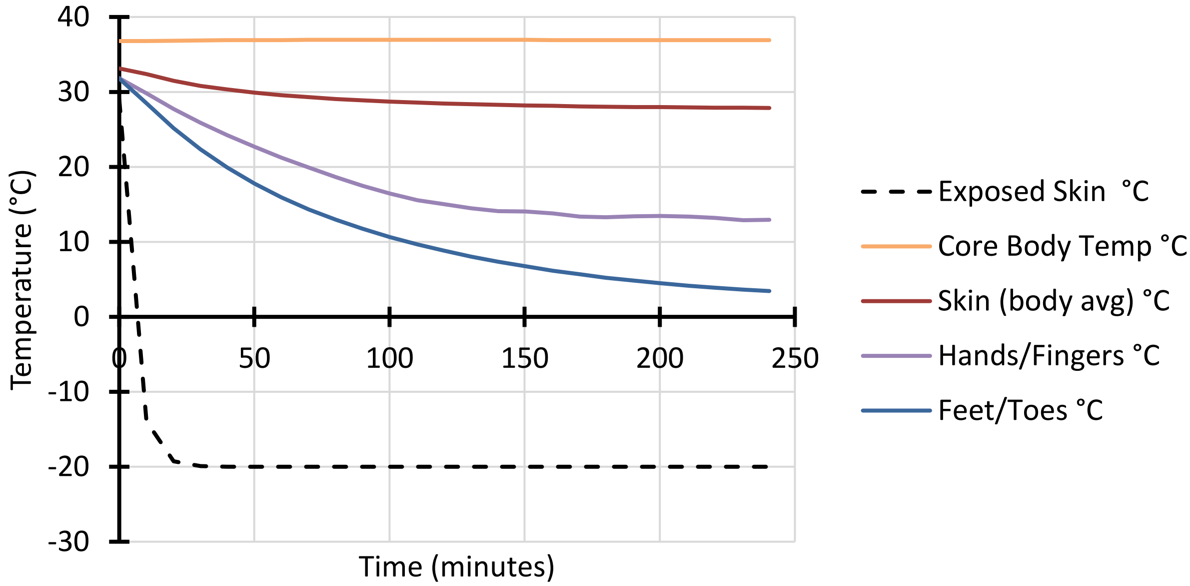


Figure 3. Clothing: light gloves and all weather boots (similar to Army light leather glove and temperate weather combat boots), **Environmental conditions:** In vehicle: Ta -8°C, 60% RH, 1 km/hr wind velocity.

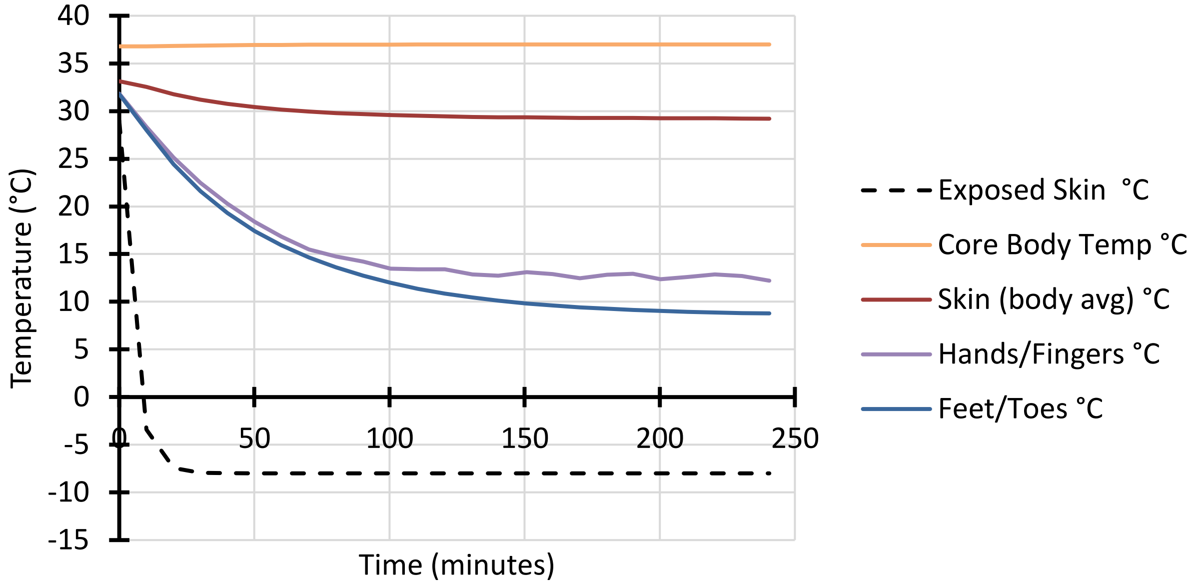


Figure 4. Clothing: light gloves and all weather boots (similar to Army light leather glove and temperate weather combat boots), **Environmental conditions:** In vehicle: Ta -20°C, 60% RH, 1 km/hr wind velocity.

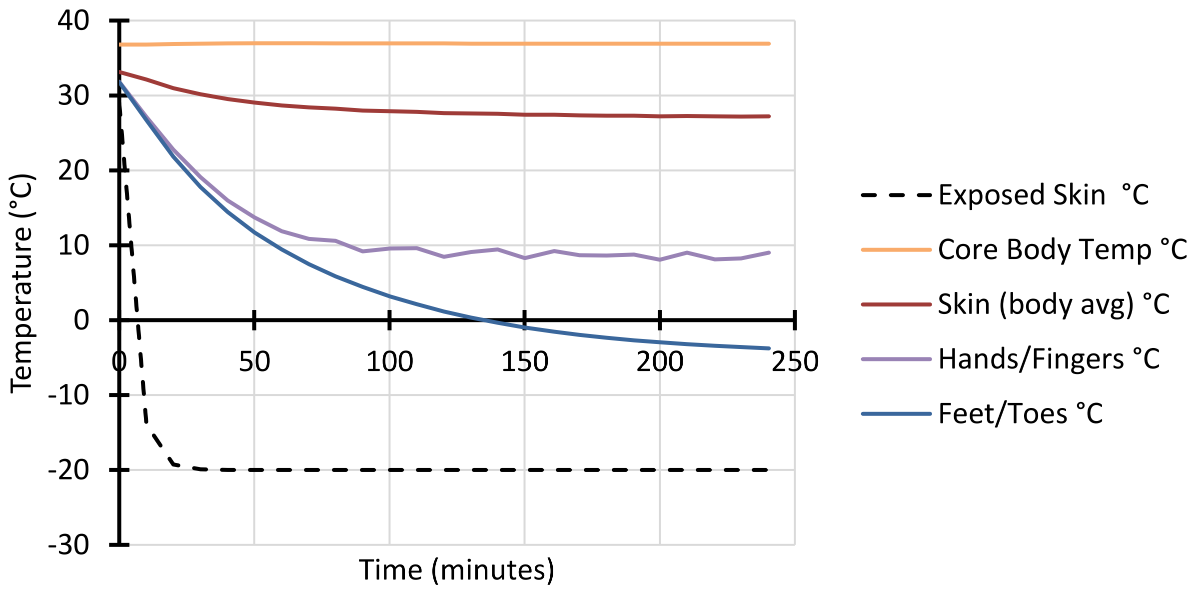


Figure 5. Clothing: mittens and cold weather boots (similar to Army mittens and VB boots), **Environmental conditions:** Ta 5°C, 60% RH, 17 km/hr wind velocity.

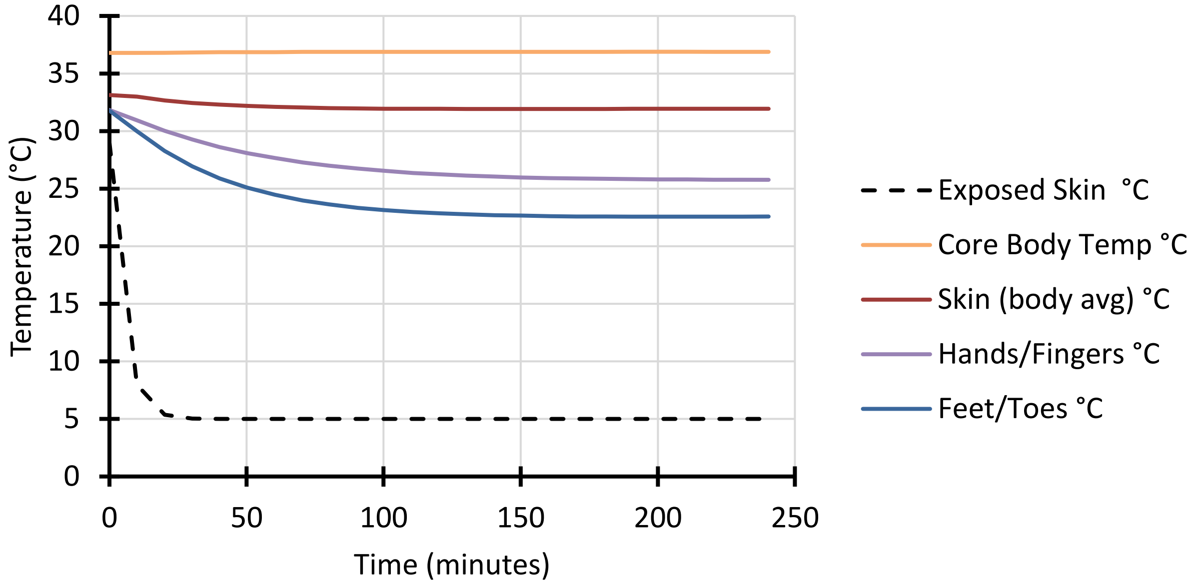


Figure 6. Clothing: mittens and cold weather boots (similar to Army mittens and VB boots), **Environmental conditions:** Ta -8°C, 60% RH, 17 km/hr wind velocity.

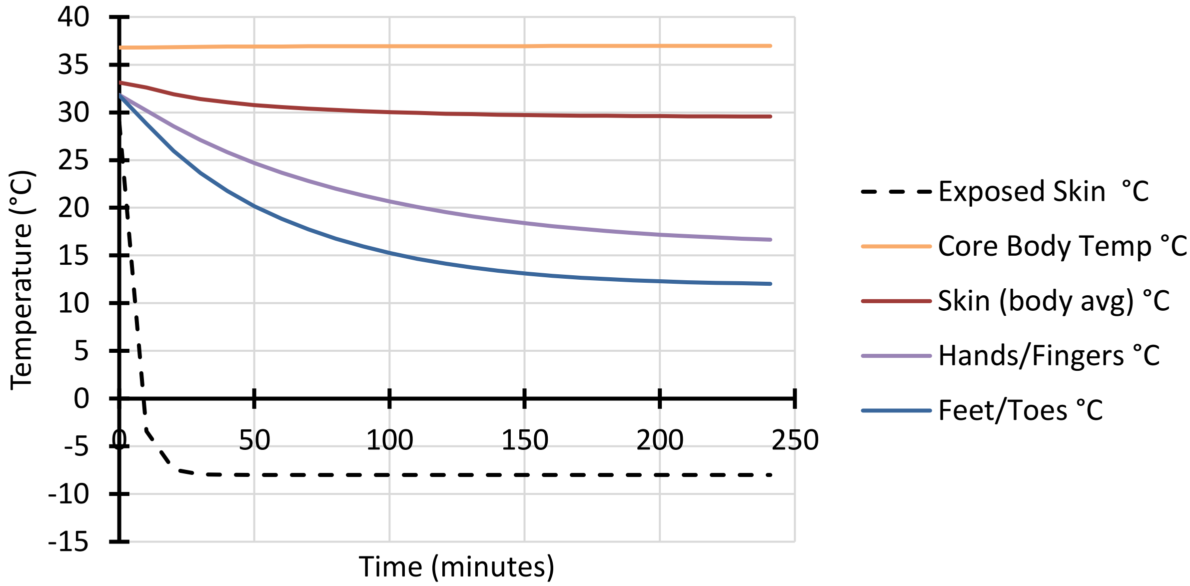


Figure 7. Clothing: mittens and cold weather boots (similar to Army mittens and VB boots), **Environmental conditions:** Ta -20°C, 60% RH, 17 km/hr wind velocity.

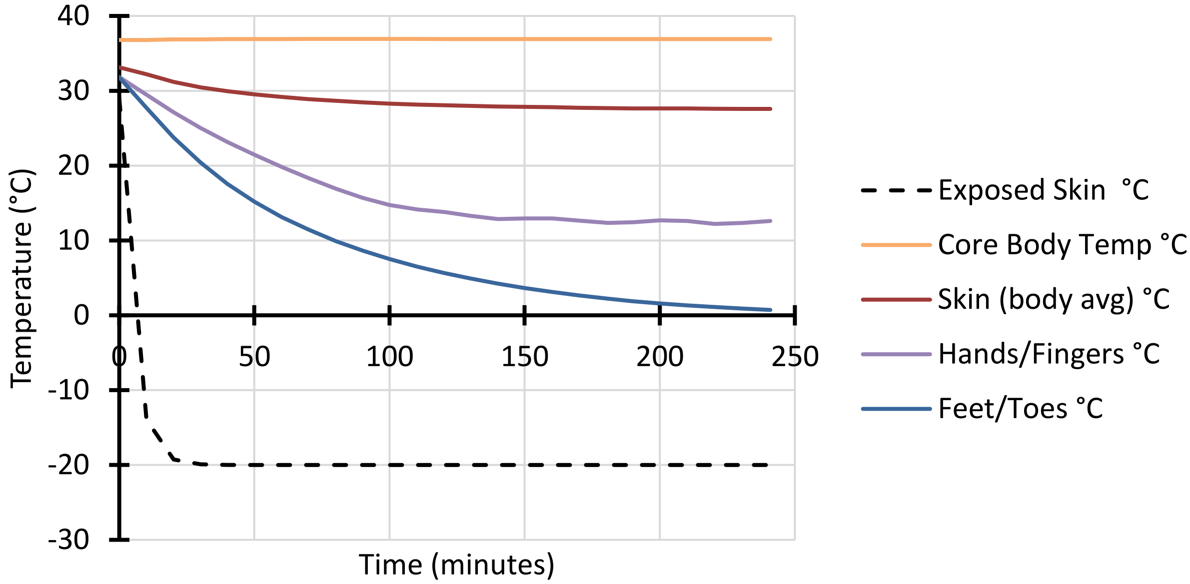


Figure 8. Clothing: light gloves and all weather boots (similar to Army light leather glove and temperate weather combat boots), **Environmental conditions:** Ta 5°C, 60% RH, 17 km/hr wind velocity.

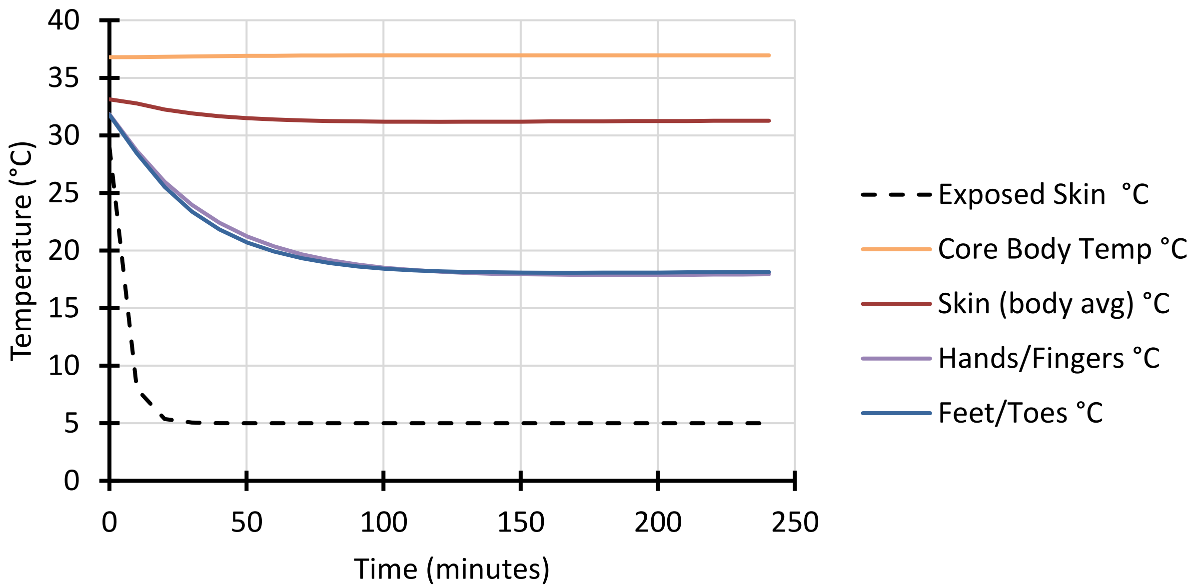


Figure 9. Clothing: light gloves and all weather boots (similar to Army light leather glove and temperate weather combat boots), **Environmental conditions:** Ta -8°C, 60% RH, 17 km/hr wind velocity.

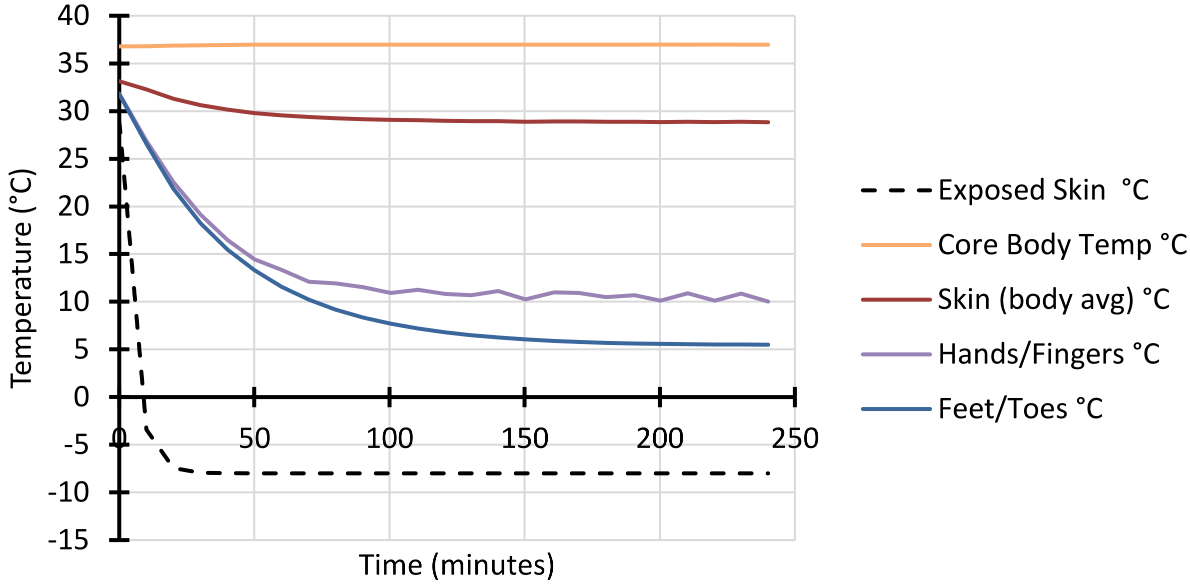
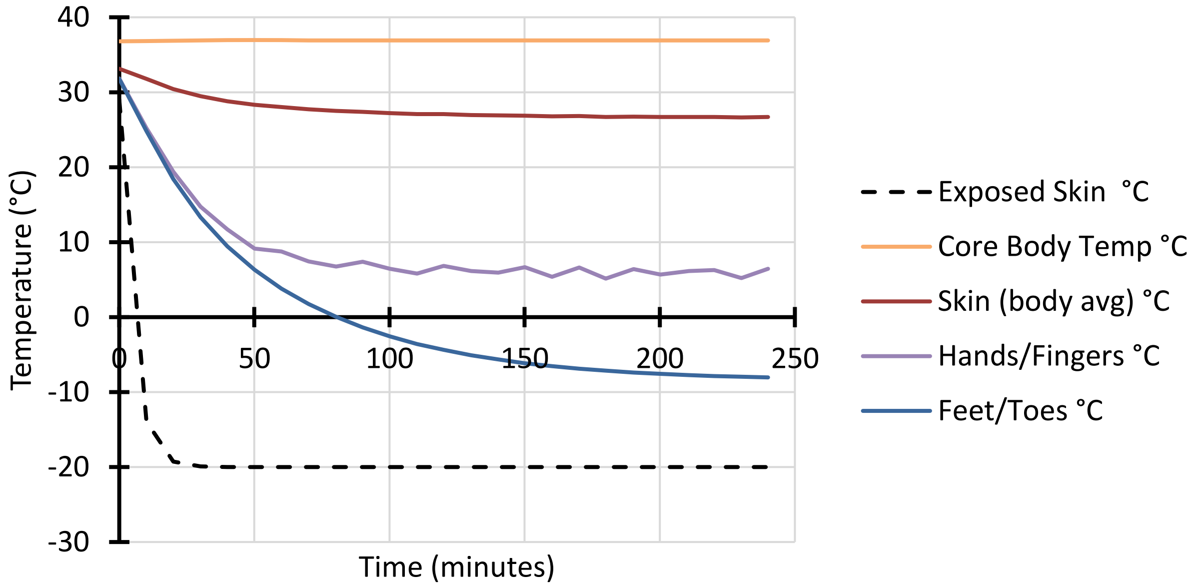


Figure 10. Clothing: light gloves and all weather boots (similar to Army light leather glove and temperate weather combat boots), **Environmental conditions:** Ta -20°C, 60% RH, 17 km/hr wind velocity.



DISCUSSION

Predictions based on available data

We made predictions about cold injury risks to Russian soldiers in their current situation as described by media sources, and on the basis of what we could establish regarding the environmental conditions, the soldiers, their activity levels, and their clothing. For this analysis, we used USARIEM's existing thermal models, along with open source estimates of the environmental conditions, made assumptions regarding the 'typical' Russian soldier and their activity, and based on some observations used comparable clothing values to make predictions. Based on these best estimates, the soldiers in this convoy were not likely to become hypothermia casualties but were likely to suffer freezing cold injuries to their feet or any exposed skin (e.g., face), especially if temperatures dipped as low as the forecast of -20°C. After the fact, the temperature did not dip that low.

Limitations of the current Computational Methods and Shift towards Artificial Intelligence (AI)

Better predictions could be made if the available artificial intelligence (AI) tools were expanded with new data and rationally-based algorithms. In this respect, high priorities would be to quantify the effects of fatigue and chronic underfeeding on cold response, established qualitatively by USARIEM in a series of studies with Winter Ranger students following the 1994 hypothermia deaths in training at Fort Benning, and to include cold-wet effects (13). Another priority would be to expand the clothing biophysics database with characteristics of Russian (and/or other peer- or near-peer) military uniforms.

General observations on the value of this predictive AI capability

The AI-based physiological prediction demonstrates what can be done today with existing mathematical physiology. These AI-prediction capabilities compress the information response timeline from weeks to hours. This capability is based on 70 years of Army efforts to systematically expand environmental physiological predictions. Initially, this required urgent seat-of-the-pants human studies. When the Army wanted to send heat acclimated soldiers from Fort Knox into the Aleutian Islands in 1943, the Armored Medical Research Laboratory (AMRL) was asked to provide clothing requirement predictions (14). Uniformed physiologists rushed to conduct experiments with two soldiers in various clothing sets walking on treadmills in a cold room to develop clothing guidance within a few weeks and they provided best available advice with limited understanding of the variability and other factors. Similar human studies produced data for design guidance for cooling and ventilation requirements in the Sherman tank. However, these early data formed the start of mathematical physiology that continues at USARIEM today to provide ever improving predictions of soldier health and performance outcomes in extreme conditions, using AI tools that can predict complex physiological interactions in minutes-hours.

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APPENDIX A.

Appendix Figure 1. Russian 8 Layer cold weather clothing system

Source: https://mensgear.net/russian-cold-camo-vkbo-russian-military-extreme-cold-weather-clothing-system/

Appendix Figure 2. Russian cold weather mittens

https://nypost.com/2022/02/28/ukraine-parades-captured-russian-soldiers-in-online-videos/

https://www.news.com.au/world/europe/captured-russian-soldiers-fear-death-by-firing-squad-we-will-be-shot-by-our-own-people/news-story/d2ac2a1fa2426a2f1e1656d90a098061

https://www.gulftoday.ae/news/2022/03/12/third-russian-general-killed-in-ukraine