Polisen

Protokollbilaga

Arkiv/Åkl. ex

Åklnr
AM-178088-22

Signerat av
Petra Johansson

Signerat datum
2023-11-07 10:47

Datum
2023-06-21

Enhet
Region Syd, BINR 3 PO S Skåne

Handläggare (Protokollförare)
Petra Johansson

Bitr. handläggare
Magdalena Csiky

Undersökningsledare
Ingegerd Jigin

Polisens diarienummer
5000-K1548032-22

Personer i ärendet

Förtursmål	Beslag	Målsägande vill bli underrättad om tidpunkt för huvudförhandlingen
Målsägande/misstänkt under 18 år		Nej
Ersättningsyrkanden		**Tolk krävs**

Misstänkt (Efternamn och förnamn)	Personnummer
Inkvist, Thord Daniel	19801228-4058
Brott	**Förhandsgodkännande enligt RB 48:10**
	Nej

Misstänkt har delgivits information om att förenklad delgivning kan komma att användas av polis och tingsrätt (skriftligt överlämnad vid ett personligt sammanträffande).
2023-02-01

Misstänkt har delgivits information om att tillgänglighetsdelgivning kan komma att användas av tingsrätt (skriftligt överlämnad vid ett personligt sammanträffande).

Underrättad om slutförd förundersökning / utredning enligt RB 23:18a	Yttrande senast (rädrum)
2023-09-15, muntlig underrättelse	2023-10-27
	Resultat av slutunderrättelse
	Erinran

Försvarare
Elvingsson, Anders, förordnad 2022-12-27

Underrättad om slutförd förundersökning / utredning	Yttrande senast (rädrum)
2023-09-15, muntlig underrättelse	2023-10-27
	Resultat av slutunderrättelse
	Erinran

Misstänkt (Efternamn och förnamn)	Personnummer
Inkvist, Jasmine	19890204-4125
Brott	**Förhandsgodkännande enligt RB 48:10**
	Nej

Misstänkt har delgivits information om att förenklad delgivning kan komma att användas av polis och tingsrätt (skriftligt överlämnad vid ett personligt sammanträffande).
2023-02-01

Misstänkt har delgivits information om att tillgänglighetsdelgivning kan komma att användas av tingsrätt (skriftligt överlämnad vid ett personligt sammanträffande).

Underrättad om slutförd förundersökning / utredning enligt RB 23:18a	Yttrande senast (rädrum)
2023-09-15, muntlig underrättelse	2023-10-27
	Resultat av slutunderrättelse
	Erinran

Försvarare
Gerleman, Ebba, förordnad 2022-12-27

Underrättad om slutförd förundersökning / utredning	Yttrande senast (rädrum)
2023-09-15, muntlig underrättelse	2023-10-27
	Resultat av slutunderrättelse
	Erinran

Notering

HYPOTERMI

Innehållsförteckning

Sakkunnigutlåtande

Formalia

2023-03-13 inkom begäran om sakkunnigutlåtande från Petra Johansson Polismyndigheten i Lund, Södra Skånes polisområde avseende ärende 5000-K1548032-22, [redacted]Zoey Inkvist.

Angående Zoey Inkvist [redacted]
Zoey Inkvist (ZI) inkom 2022 12 24 klockan 04.43 till Barnakuten Lund efter intag av ca 50–150 ml 24 % ättiksprit. Vid ankomst till sjukhuset var hon medvetandesänkt. Hon företedde tecken till nedkylning i form av så kallad blåmarmorering och perifer kyla. Kroppstemperaturen vid mätning i ändtarmen var 33,9ºC.

Petra Johansson (PJ) kontaktade undertecknad 2023 03 07 med förfrågan om sakkunnigutlåtande/sakkunnigförhör avseende låg kroppstemperatur/hypotermi, i ett brottmål som gällde synnerligen grov misshandel (ej vållande till annans död). Formell begäran från Petra Johansson Polismyndigheten i Lund och kammaråklagare Ingegerd Jigin (IJ) Södra Skånes åklagarkammare inkom 2023-03-13 mot bakgrund av att Rättsmedicinalverkets rättsintyg inte besvarade alla frågor avseende ZI:s låga kroppstemperatur.

Bakgrundsinformation

Sammanfattning av polisens utredningshandlingar, rättsintyg från Rättsmedicinalverket, patientjournaler från sjukvården och temperaturuppgifter från SMHI.

ZI var vid händelsen 6 år och 11 månader. ZI är för tidigt född, v 31 + 4. Föräldrarna Daniel Inkvist (DI) och Jasmine Inkvist (JI) uppgav att ZI är sent utvecklad och bär blöja i hemmet. ZI har ingen känd medicinering. DI uppgav att ZI haft maginfluensa från ca 2023 12 10-12 som slutade ca 2023 12 15-17.

Enligt fadern DI gick ZI och lade sig vid ca klockan 20–21, 2023 12 23. Mamman JI uppgav att hon väcktes vid ca klockan 03–04 av att ZI kom till henne och gnydde och det lät som att hon hade ont i magen. Pappan väcktes av JI varefter han gick till tvättstugan där han uppdagade att ett glas med ättiksprit som han ställt på torktumlaren var tomt varför han misstänkte att ZI hade druckit upp det. DI uppgav att glaset innehållit ca 0,5 dl medan JI trodde att det innehållit mer, ca 1,5 dl. ZI som under natten enbart haft blöja fick ny blöja, strumpor, mjukisbyxor, tröja och vinterjacka varefter DI med egen bil körde till sjukhuset. JI uppgav att ZI inte var kall vid avfärden, att hon var helt talför och medveten, gick själv, vinkade och sa hej då. Bilen var enligt DI kall vid start men inom 5 min uppgav DI att det var varmt i kupén. Tiden för bilfärden uppskattades till ca 20–25 minuter.

Vi inkomsten till Barnakuten Lund var ZI kraftigt medvetandesänkt på gränsen till medvetslös. ZI var rejält nedkyld, blåmarmorerad och kroppstemperaturen uppmättes i ändtarmen till 33.9ºC.

Vikt var 16,2 kg vilket utgör minus 2,92 standardavvikelser jämfört med normal tillväxt. Längd 117 cm. ZI hade vid inkomsten till sjukhuset normalt blodtryck, puls ca 90 slag/min. Det var svårt att känna puls vid artären i handleden men pulsen kunde kännas i ljumsken. ZI hade långsam andning med 3–4 andetag per minut och hon beskrevs vara lättblödande. Det gick inte att mäta syremättnad i blodet. ZI:s ultraljud av hjärtat visade nedsatt kammarfunktion. ZI hade uttalade frätskador i matstrupe och magsäck vilket gjorde att hennes magsäck permanent opererades bort.

Vid den rättsmedicinska undersökningen 2022 12 27 sågs en magerlagd flicka med brunaktig smutsbesudling ställvis på kroppen. Vidare sågs blåmärken på de båda armarna, sår, sårskorpor och överhudsförlust på säteshalvorna och i underlivet samt "märken" på/kring fotlederna.

Temperaturen utomhus natten mot 2022 12 24 var enligt SMHI plus 0,7°C ned till minus 2,5°C. Inomhustemperaturen i hemmet uppgavs av DI till 19–20°C. Polisens tekniker uppmätte 2022 12 27 temperaturen i huset till 15,4°C.

Sammanfattning av bildmaterial

Av fotobilaga till rättsintyg på ZI (Rättsmedicinalverket diarenr:5000-K1548032-22 Fnr: D22-R0481) framgår att det i nedre delen av ryggen över sätesregionen och i underlivet finns talrika 0,5–1 cm stora antydd rundade ytliga sår, dels belagda med brunröd skorpa dels med blottad rödaktigt intorkad läderhud.

Särskilda frågeställningar från Polismyndigheten (PJ) och åklagaren (IJ)

Fråga 1: Går det att ange hur lång tid det tar att nå kroppstemperatur 33,9°C vid omgivningstemperaturerna 20–19°C, 15°C eller utomhus +0,7C° ned till -2,5C°?

Fråga 2: Kan intag av 50–150 ml 24% ättiksprit ha bidragit till att utveckla hypotermi med kroppstemperatur 33,9°C?

Fråga 3: Medför hypotermi kombinerat med frätskadorna av ättiksprit en risk för hälsa eller liv?

Fråga 4: Vet man hur kroppstemperaturen sjunker, tar den hopp eller stadigt bit för bit?

Fråga 5: Hur fysiskt aktiv man är vid 33,9°C, hur är kroppen rent motoriskt?

Överväganden

Detta rör sig om en vid tidpunkten 6 år och 11 månader gammal flicka med uttalade frätskador i matstrupe och magsäck efter intag av ättiksprit samt med en kroppstemperatur 33,9°C.

Nedkylning i en omgivning med låg omgivningstemperatur och/eller lång exponeringstid och där vi inte kan skydda oss, eller producera tillräckligt mycket värme för att behålla en kärntemperatur på 37°C, leder till hypotermi. Den medicinska definitionen för accidentell hypotermi är en kroppstemperatur på 35°C eller lägre. Kylskador omfattar allmän nedkylning (hypotermi) och lokala kylskador. Det kanske tidigaste tecknet på nedkylning är en önskan om att finna värme. Minnet och omdömet försämras på ett tidigt stadium personen talar sluddrigt och medvetandet grumlas. Nedkylning, redan i stadiet från 37°C ned till 35°C leder till huttring som del i att öka värmeproduktionen. Huttringen är inte viljestyrd utan styrs helt automatiskt och den är maximal vid ca 35°C. Huttring avtar succesivt och vid 33°C har de flesta slutat att huttra. Tidigt ses en generell kärlsammandragning i armar och ben, händer och fötter i syfte att spara värme centralt, följt av en förhöjd puls med ökad belastning på hjärtat och en ökad andningsfrekvens. Från 35°C och nedåt kyls hjärtat successivt ner med en tilltagande förlångsamning av puls och andningsfrekvens. Vid 34°C har man tydligt passerat gränsen för hypotermi, oftast med apati, men ibland även med psykosliknande symtom som hallucinationer. Ångest, oro och tilltagande medvetandepåverkan liksom tilltagande gång-, balans- och koordinationssvårigheter är regelmässigt förekommande delar i den kliniska bilden och tilltar med sjunkande kroppstemperatur. Om personen inte tas ur situationen och tillförs värme kommer kroppstemperaturen fortsatt att sjunka. Vid 30°C är de flesta tydligt medvetandesänkta, vissa är medvetslösa. Vid kroppstemperatur under 28°C är hjärtat mycket känsligt för yttre stimuli och kan vid ovarsam hantering gå över i kammarflimmer som betyder att hjärtat de facto inte pumpar längre. Vid 25°C och därunder kan hjärtat spontant stanna helt (så kallad asystoli) eller gå över i kammarflimmer. Hypotermi påverkar ett antal av kroppens funktioner däribland blodets levringsförmåga och den hypoterma patienten blir med sjunkande kroppstemperatur alltmera lättblödande. Vid ca 33°C är koagulationsförmågan nedsatt till omkring 50 % av det normala något som ses både i blodprover och kliniskt. Ett problem är dock att blodprover normalt analyseras vid 37°C varför provsvaren kan uppfattas normala medan patienten är lättblödande. Kombinationen av stort trauma, som exempelvis samtidig lårbensfraktur och bukblödning, och hypotermi ned till 33°C har visats öka risken för död med upp till 40 % jämfört med motsvarande risk hos personer med normal kroppstemperatur. Det ska dock påpekas att det finns stora individuella skillnader för hur olika personer påverkas av nedkylning.

Det framgår av journalhandlingar att ZI vid inkomsten till sjukhuset hade uttalade tecken på accidentell hypotermi med låg kroppstemperatur 33,9°C, sänkt medvetandegrad, uttalad perifer kyla, sammandragna perifera blodkärl, blåmarmorerad hud och var tydligt lättblödande. Informationen som JI gav, att ZI inte var kall, att hon var helt talför och medveten, gick själv, vinkade och sa hej då till mamman inför avresan till sjukhuset är därför motsägelsefull. Likaså är informationen från DI inför bilresan till sjukhuset, om att hon definitivt inte var kall, motsägelsefull.

Faktorer som ska vägas in för att förstå uppkomsten av hennes hypotermi är: längd, vikt, kroppsyta, klädsel, omgivningstemperatur, tiden hon utsatts för kyla dvs exponeringstid, nutritionsstatus och andra samtidiga sjukdomar eller skador.

Kroppsvikt, längd och kroppsyta är väl kända hos ZI. Klädsel och nutritionsstatus framgår av journalhandlingar, polisutredning och uppgifter från föräldrarna. Faktorerna omgivningstemperatur och exponeringstid är okända. I en matematisk modell av Tikuisis, Giesbrecht och medarbetare, se bilaga, för att hypotisera hur hypotermi har uppstått hos ZI kan följande antaganden göras. Om ZI hade enbart blöjor och omgivningstemperaturen inomhus varit 19–20°C, vilket föräldrarna uppgett, skulle det krävas en exponeringstid på mer än 36 timmar för att nå 33,9C. Om omgivningstemperaturen varit 15°C, vilket polisens tekniker uppmätt i tvättstugan, skulle det krävas en exponeringstid på 26 timmar för att nå 33,9°C. Om omgivningstemperaturen utomhus varit omkring 0°C, enligt SMHI + 0,7°C ned till -2,5°C under natten skulle det krävas en exponeringstid på 3–3,5 timmar för att nå 33,9°C. Under färden till sjukhuset där ZI hade kläder med sockar, mjukisbyxor, tröja, vinterjacka och den uppskattad omgivningstemperaturen i bilen varit 0°C-15°C skulle det krävas en exponeringstid på mer än 26 timmar för att nå 33,9°C.

ZI har en vikt som avviker nedåt med 2,92 SD från normalvikt för åldern och kan därför antas vara undernutrierad. ZI hade också talrika ytliga sår i nedre delen av ryggen, över sätesregionen och underlivet. Dessa är faktorer som kan påverka ZI negativt innebärande att hon sjunkit något snabbare än de ovan hypotiserade exponeringstiderna.

ZI har intagit ättiksprit och en frågeställning har varit om det kan förklara, eller kan ha bidragit till hennes hypotermi. Systemupptaget efter intag av ättiksyra är vanligen begränsat (utom vid mycket stora intag) medan det främsta problemet är lokal frätskada i matstrupe och magsäck. Ättiksprit ger en uttalad kramp i nedre magmunnen som gör att ättikan stannar i magsäcken där upptaget är i det närmaste obefintligt. Det finns inte några erfarenhetsmässiga, eller vetenskapliga belägg för att ättiksprit eller frätande substanser skulle bidra till hypotermi varför hennes intag av ca 50–150 ml 24 % ättiksprit i det här avseendet inte kan vägas in vid bedömningen av hur hennes hypotermi hur uppkommit.

4/C

Sakkunnigutlåtande

Fynden, det vill säga ZI:s symptom visar att ZI vid inkomsten till sjukhuset var hypoterm.

Fynden talar starkt för att ZI har exponerats för kyla under lång tid, där den kortaste tiden i kombination med omgivningstemperatur omkring 0°C utomhus skulle ha varit 3 timmar.

Fynden är vidare förenliga med att ZI har exponerats för en omgivningstemperatur om 15°C under 26 timmar eller mera.

Fynden talar starkt emot den beskrivning som föräldrarna har lämnat, det vill säga att ZI har vistats inomhus med omgivningstemperatur 19–20°C, och är inte heller förenliga med att ZI skulle ha varit opåverkad vid avfärd till sjukhuset och ha utvecklat sin hypotermi under färden in till sjukhuset.

Fynden talar starkt emot att intaget av ättiksprit skulle kunna förklara ZI:s hypotermi. Vare sig i de inkomna handlingarna eller i den medicinska litteraturen finns det något som stödjer ett antagande om att intag av ättiksprit skulle ha utvecklat hennes hypotermi.

Svar på särskilda frågeställningar

Fråga 1: *Går det ange hur lång tid det tar att nå kroppstemperatur 33,9°C vid omgivningstemperaturerna 20–19°C, 15°C eller utomhus +0,7°C ned till -2,5°C?*

Svar: Med blöjor enbart och en omgivningstemperatur på 20–19°C tar det mer än 36 timmar att nå 33,9°C. Med blöjor enbart och omgivningstemperatur 15°C tar det 26 timmar att nå 33,9°C. Med blöjor enbart och omgivningstemperatur +0,7 ned till-2,5°C °C tar det 3–3,5 timmar att nå 33,9°C. Se även rubriken överväganden ovan.

Fråga 2: *Kan intag av 50–150 ml 24 % ättiksprit ha bidragit till att utveckla hypotermi med kroppstemperatur 33,9°C?*

Svar: Frågan är besvarad ovan. Nej, ett intag av 50–150 ml 24 % ättiksprit bedöms inte ha bidragit till ZI:s hypotermi.

Fråga 3: *Medför hypotermi kombinerat med frätskadorna av ättiksprit en risk för hälsa eller liv?*

Svar: Den mycket låga kroppstemperaturen har inneburit att ZI har försatts i ett livshotande tillstånd. De omfattande frätskadorna av ättiksprit är en försvårande omständighet med de åtföljande åtgärder som de föranledde.

Fråga 4: *Vet man hur kroppstemperaturen sjunker, tar den hopp eller stadigt bit för bit?*

Svar: Kroppstemperaturen sjunker kontinuerligt och inte stegvis. Förändring av omgivningsfaktorer som sjunkande omgivningstemperatur, tillkomst av vind eller väta påverkar hastigheten för hur kroppstemperaturen sjunker. Likaså minskar förmågan att producera egen värme när huttringen avtar, och vid ca 33°C slås ut vilket gör att kroppstemperaturen då sjunker snabbare.

Fråga: *5 Hur fysiskt aktiv man är vid 33.9^{o}C, hur är kroppen rent motoriskt?*

Svar: Vid hypotermi ses ofta en tilltagande apati och tilltagande gång-, balans- och koordinationssvårigheter vilka tilltar med sjunkande kroppstemperatur. I det enskilda fallet kan man inte uttala sig om graden av påverkan vid en specifik kroppstemperatur.

Förklaring av beräkningsmodellen

I den matematisk modellen av Tikuisis, Giesbrecht och medarbetare, se bilaga, tas hänsyn till ålder, längd, vikt, kroppsfett, omgivningstemperatur, vind, väta, klädsel och expositionstid. Tider för hur snart ZI kan kalkyleras nå till kroppstemperatur 33,9^{o}C beräknades i modellen.

Förklaring av vilka data som angetts i beräkningsmodellen
I modellen angavs följande data för ZI: 7 år, 16,2 kg, längd 117 cm, två klädesvarianter, den ena med blöja enbart den andra med sockor, mjukisbyxor, tröja och tjockare jacka tjockare jacka, omgivningstemperaturer 20–19^{o}C, 15^{o}C, 0^{o}C.

Umeå 2023–05–24

Helge Brändström

Överläkare
Specialist i Allmänmedicin 1988
Specialist i Anestesiologi och intensivvård 1989
Medicine doktor 2012, disputerad inom ämnesområdet hypotermi och kylskador

Gordon Giesbrecht, Ph.D., FAsMA, FAWM

Legal Consultant
Thermophysiologist
Professor and lecturer
www.umanitoba.ca/kinrec/giesbrecht

92 Colebrook Dr.
Winnipeg, MB Canada R3T 5Y8
Phone (204) 995-6599
gordon.giesbrecht@umanitoba.ca

Date: April 27, 2023

To: Helge Brandstrom

Re: Child hypothermia case

I have been asked to provide answers to the following case.

INFORMATION PROVIDED:

Situation:
6-year-old girl, close to seven, born 2016 01 09
Length 117 cm
Weight 16.2 Kilogram
Arrived at ED at university hospital 2023 12 24 05.00 AM. After intake of 50-150 ml 24% vinegar essence at about 03.30 AM.

Assessment at the ED room
T rectal 33.9°C
Semiconscious with Glasgow Coma Scale 9-10, very drowsy, responds to strong stimulation (loud talk, shaking, pain stimulation).
Cyanotic
Peripherally cold and vasoconstricted
Radial pulse not palpable
Respiratory Rate 4-5/minute
Heart Rate 90 beats/minute
Bleed easily

Clothing:
Diaper only at home
In car on way to hospital, 20-25 minutes' drive, shoes, socks, diaper, trousers, women's sweater, women's winter jacket

According to police investigation:
Tied down and immobilized to mobile child car safety seat in laundry room.
Temperature in laundry room from police investigation 15°C
Temperature in house from parents' description 19-20°C

Temperature outdoors 0.7°C (06.00 PM the evening before) down to -2.5 (06.00 AM the day when she came into the hospital)
Superficial wounds at lower back and lower abdomen, buttocks, and genital area.

According to parents:
The girl had been sleeping in their master bedroom and came in groaning from pain in her stomach.
Telling she had been drinking vinegar essence from a glass in the laundry room.
Fully awake, not especially cold, waved goodbye to her mother while ready for the car drive with her father to hospital.

<u>QUESTIONS</u>

1) How long would it take to cool down to a core temperature of 33.9°C.

a. With diaper only (screen shots of the model predictions are included on next page):
   i. In 0°C air – 3 hours (Figure 1)
   ii. In 15°C air – 26.6 hours (Figure 2)
   iii. In 19°C air - >36 hours (Figure 3)
b. With sweater and parka on:
   i. In 0°C air - >36 hours (Figure 4)
   (this is the maximum time the model predicts for)
   Thus, at 15 or 19°C air, the predicted time would also be > 36 hours.

2) Comparative effects of being immobilized or mobile.
I do not think there would be much effect of being immobilized compared to mobile in a cold environment.

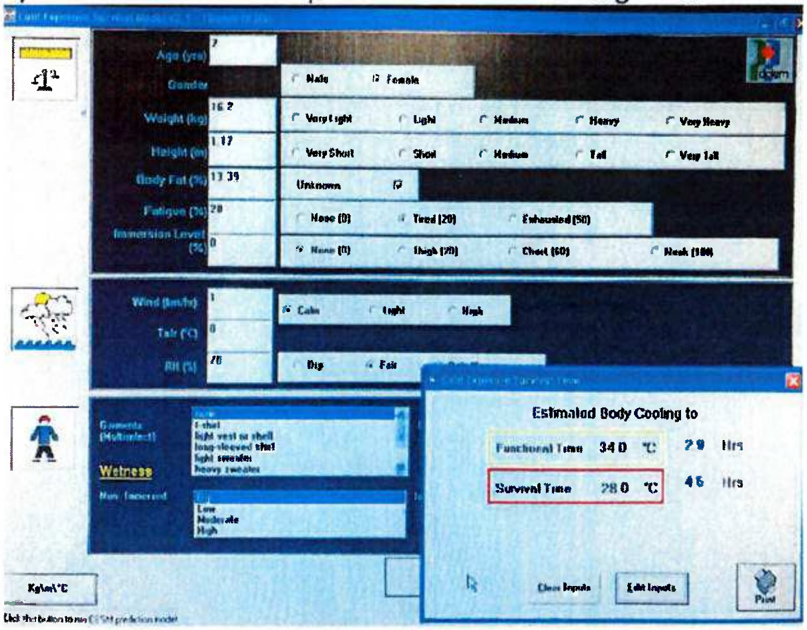
3) Effect of diapers being wet from urine only.
A wet diaper (especially if it is a disposable one) would have little effect on core cooling rates.

4) **Effect of clothing shoes, socks, diaper, trousers, women's sweater, women's winter jacket**
This clothing would essentially prevent core cooling as noted above.
The predictions to reach a core temperature of 34°C assumes no clothing on the torso.

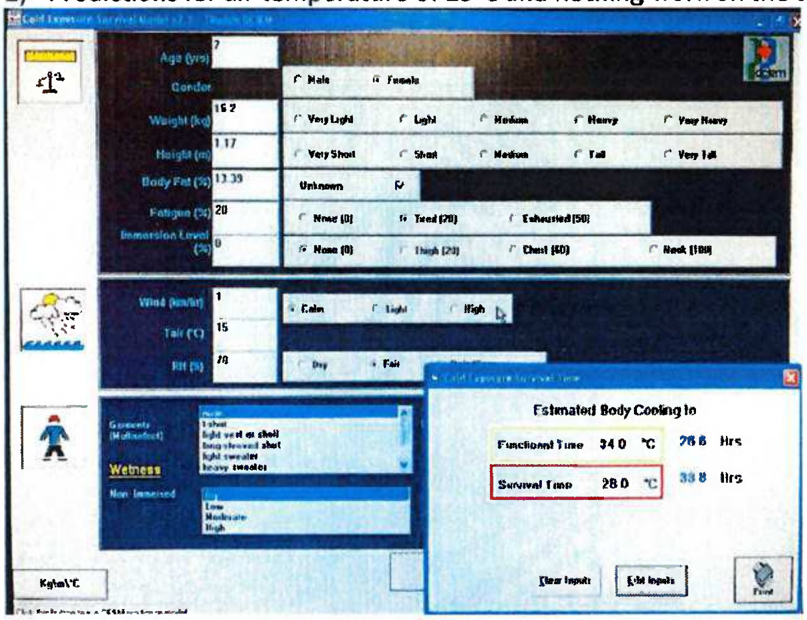
T environment 19°C (>36 hours)
T environment 15°C (26.6 hours)
T environment 0°C (3 hours)

With the clothing noted above, the time to reach a core temperature of 34°C would be > 36 hours at 0, 15 or 19°C air temperatures. Whether the victim was in the house and/or in the car for 20-25 minutes, would not affect these predictions.

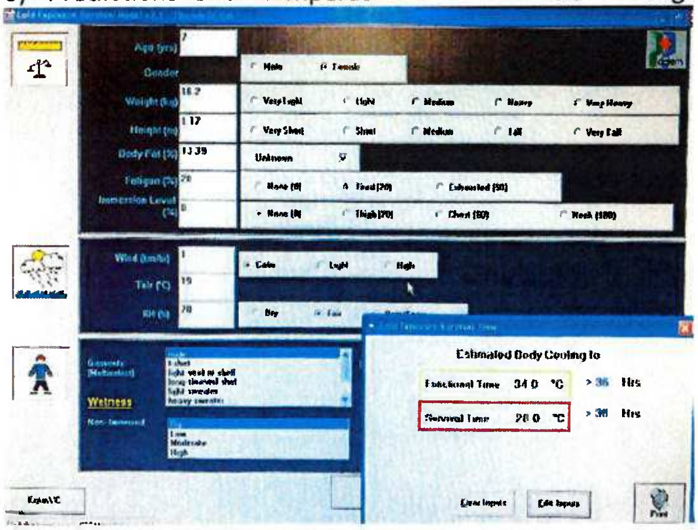
1) **Predictions for air temperature of 0°C and nothing worn on the torso.**



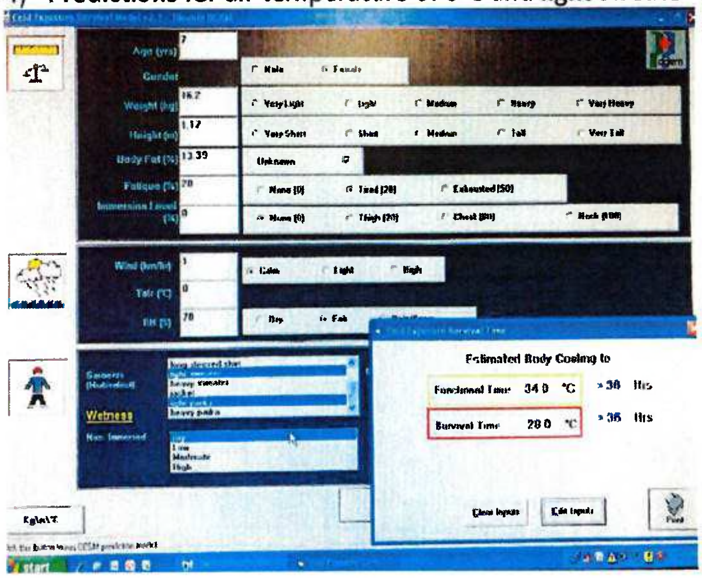
2) **Predictions for air temperature of 15°C and nothing worn on the torso.**



3) Predictions for air temperature of 19°C and no clothing on the torso.



4) Predictions for air temperature of 0°C and light sweater and parka on the torso.



Thank you for the opportunity to assist in this matter.

Sincerely,

Gordon Giesbrecht, Ph.D.

Computers in Biology and Medicine

ELSEVIER Computers in Biology and Medicine 35 (2005) 287–298

http://www.intl.elsevierhealth.com/journals/cobm

Thermoregulatory model for prediction of long-term cold exposure

Xiaojiang Xu[a,*], Peter Tikuisis[b], Richard Gonzalez[a], Gordon Giesbrecht[c]

[a] *Biophysics and Biomedical Modeling Division, US Army Research Institute of Environmental Medicine, Kansas Street, Natick MA01760, USA*

[b] *Defence Research and Development, Simulation and Modeling for Acquisition, Rehersal and Training, 1133 Sheppard Avenue West, Toronto PO Box 2000, Ontario, Canada M3M 3B9*

[c] *Laboratory for Exercise and Environmental Medicine, University of Manitoba, Winnipeg, Canada R3T 2N2*

Received 26 June 2003; received in revised form 20 October 2003; accepted 28 January 2004

Abstract

A multi-segmental mathematical model has been developed for predicting shivering and thermoregulatory responses during long-term cold exposure. The present model incorporates new knowledge on shivering thermogenesis, including the control and maximal limits of its intensity, inhibition due to a low core temperature, and prediction of endurance time. The model also takes into account individual characteristics of age, height, weight, % body fat, and maximum aerobic capacity. The model was validated against three di erent cold conditions i.e. water immersion up to 38 h and air exposure. The predictions were found to be in good agreement with the observations.

Keywords: Mathematical model; Thermoregulation; Shivering; Cold stress; Hypothermia

1. Introduction

Thermal modeling is useful for understanding and predicting human responses to extreme conditions, whether by degree or duration (e.g., long exposure to cold air or water). Such models are especially valuable for predicting responses under conditions that cannot be tested ethically using human volunteers. Their application is very broad-based, from analyzing possible scenarios for rescue organizations to assisting post mortem criminal investigations.

* Corresponding author. Tel.: +1-508-233-4805; fax: +1-508-233-5298.
E-mail address: xiaojiang.xu@na.amedd.army.mil (X. Xu).

0010-4825/$ - see front matter © 2004 Published by Elsevier Ltd.
doi:10.1016/j.compbiomed.2004.01.004

Predictive models for long-term exposure to cold are quite limited, because of the lack of information on human responses to these conditions for extended periods of time. Most of these original thermoregulatory models' predictions are extrapolated to conditions of deep hypothermia, but they do not fully consider shivering exhaustion [1–4]. This factor is an important determinant of the balance between heat production and heat loss over a long duration. Tikuisis [5] has developed a shivering exhaustion model and incorporated it into a single-cylinder model of basic thermoregulation for predicting survival time of prolonged cold exposure. However, this model does not consider regional aspects in the body (e.g. composition, blood ow, etc.) nor their contribution to temperature regulation.

The six-cylinder model of human temperature regulation developed by Xu and Werner [6] is a suitable alternative for examining whole body response to extreme conditions. This model has been validated for heat and cold stress, various exercise loads, and for various clothing ensembles, but only for limited durations. When applied for long-term cold exposure, the model predicts that a thermal steady state can be maintained inde nitely as long as shivering is not fatigued. Clearly, shivering exhaustion must be taken into account for a more realistic prediction. The purpose of this study is to further develop the six-cylinder model of Xu and Werner by incorporating the control of shivering intensity using results from several previous studies [2,5,7,8] so that the revised model can be used to predict whole body human thermoregulatory response to long-term cold exposure.

2. Methods

The six-cylinder model of Xu and Werner [6] is subdivided into segments representing the head, trunk, arms, legs, hands, and feet. Each segment is further concentrically divided into compartments representing the core, muscle, fat, and skin. The integrated thermal signal to the thermoregulatory controller is composed of the weighted thermal input from thermal receptors at various sites distributed throughout the body. The di erence between this signal and its threshold activates the thermoregulatory actions: vasomotor changes, metabolic heat production and sweat production. Revision of the model to incorporate shivering is detailed below, but rst we describe the control of shivering intensity to aid in the conceptualization of the model.

2.1. Shivering intensity

Various aspects of the shivering response are de ned and shown schematically in Fig. 1. Shivering increases metabolism above basal values (line A) according to the integrated thermal cold signal from core and skin receptors. Shivering metabolism (M_{shiv}) increases as core (T_c) and skin (T_s) temperatures decrease (line B), as predicted according to Tikuisis and Giesbrecht [7] until a maximal value (line C) is attained. Maximal M_{shiv} has been predicted to occur at skin temperatures between 17 and 20°C [8,9], and is dependent on the maximal aerobic capacity but inversely proportional to age and the body mass index [8]. Therefore, the primary shivering response includes the theoretical maximum response to a maximal stimulus when $T_s \sim 20°C$ and $T_c \sim 32°C$ (line B–C), and a submaximal response when $T_s < 20°C$ with a constant T_c (line B–D) or when T_c is gradually decreasing (line B–E). However, M_{shiv} may be lower than expected, secondary to either shivering inhibition (line F, when $T_c < 32°C$) [5] and/or shivering fatigue (line G, when metabolic substrates are limited) [2,5].

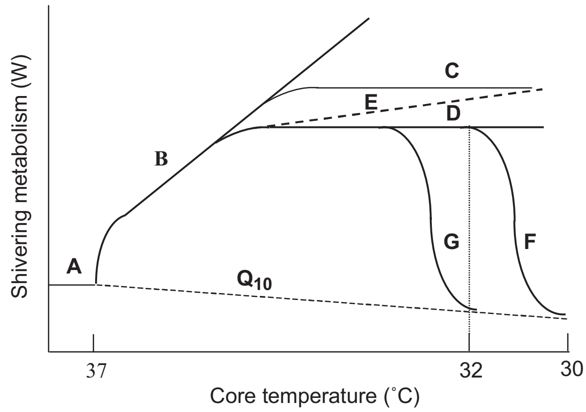


Fig. 1. Conceptual model for control of shivering intensity. (A) basal metabolism, (B) predicted shivering intensity, (C) theoretical maximum shivering intensity, (D) observed shivering plateau when $T_s < 20°C$ and T_c constant, (E) observed shivering intensity as T_c decreases or T_s nears 20°C, (F) thermoregulatory inhibition when $T_c < 32°C$, (G) shivering fatigue when shivering time exceeds the endurance time, and (Q_{10}) tissue temperature/metabolism relationship in absence of shivering.

2.2. Metabolic heat production

The primary shivering response (B of Fig. 1, $M_{\text{shiv},1}$) was predicted using the following expression derived from steady state metabolic heat production data from three separate studies [7]:

$$M_{\text{shiv},1^\circ} = \frac{155.5 \cdot (37 - T_c) + 47.0 \cdot (33 - T_s) - 1.56 \cdot (33 - T_s)^2}{\sqrt{\%\text{BF}}} \tag{1}$$

where $M_{\text{shiv},1^\circ}$ is in W/m^2, T_c and T_s are the core and mean skin temperatures (°C), respectively, and BF is body fat. Eq. (1) is particularly suited for predictions involving long-term cold exposure, as the data included in its derivation T_c as low as 33.25°C during immersion in 8°C cold water for up to 70 min. The maximal shivering intensity (line C), that M_{shiv} cannot exceed, is estimated by the following recently developed equation [8]:

$$M_{\text{shiv,max}} = 30.5 + 0.348 \cdot V_{O_2\text{max}} - 0.909 \cdot \text{BMI} - 0.233 \cdot \text{Age} \tag{2}$$

where $M_{\text{shiv,max}}$ is in ml O_2/min kg, $V_{O_2\text{max}}$ is the maximal O_2 consumption (ml O_2/min kg), BMI is the body mass index (weight/height^2 in kg/m^2), and Age is age in years. Eqs. (1) and (2) de ne the primary shivering response ($M_{\text{shiv},1^\circ}$).

The secondary shivering response (line F of Fig. 1, $M_{\text{shiv},2^\circ}$) has been empirically de ned by a hyperbolic secant function that smoothly and sigmoidally reduces shivering by a factor of 100 as T_c decreases from 32°C to 30°C as follows [5]:

$$M_{\text{shiv},2^\circ} = M_{\text{shiv},1^\circ}\,\text{sech}\{2 \cdot (32 - T_c)^{1.4}\} \tag{3}$$

When T_c decreases below 30°C, shivering is essentially arrested and any further metabolic heat production varies according to Q_{10} e ects [5].

Estimation of shivering exhaustion is presently based on a "glycogen-depletion" model [2] that assumes that time to exhaustion decreases exponentially as the relative intensity of shivering approaches a maximum value:

$$t_{end} = \frac{\ }{L_r} e^{-4.0L_r} \tag{4}$$

where t_{end} is endurance time (the time until fatigue onset) in hours, is a calibration factor having a value of 18 that corresponds to observed shivering fatigue during shivering [2], and L_r is the relative shivering intensity

$$L_r = \frac{M_{shiv,1^o}}{M_{shiv,max}} \tag{5}$$

Eq. (4) was found to be satisfactory in a recent study [10] where the onset of shivering fatigue was analyzed with experimental water immersion data.

Tikuisis [5] developed a method to calculate t_{end} when shivering intensity varies. The end of endurance is predicted when $\sum \ t/t_{end}$ equals unity where t is the time step and t_{end} is the endurance time corresponding to the shivering intensity calculated for that time step. After shivering fatigue onset, secondary shivering due to fatigue (line G of Fig. 1) is assumed to continue, but at an intensity that is reduced by the following empirical factor:

$$M_{shiv,2^o} = M_{shiv,1^o} \operatorname{sech}\left\{\frac{\frac{\sum \ t}{t_{end}} - 1}{\ }\right\} \tag{6}$$

where is a tting constant with a value of 0.38.

2.3. Blood ow to muscle

Peripheral vasoconstriction redistributes blood ow away from the extremities and skin during cold exposure. This heat conservation measure diminishes the heat transfer from the core to the skin surface. For example, basal blood ow in the extremities of the calf and forearm is reduced from 3 (ml/100ml tissue min) to near zero (nutritive only) during cooling [11]. This reduction has also been attributed to a reduced muscle blood ow [12–14]. Shivering, however, demands increased muscle blood ow, expressed as

$$Q - Q_0 = \ a + \ M_{shiv} \tag{7}$$

where Q (m^{3}blood/h m^{3}tissue) is the required muscle blood ow, Q_0 is basal muscle blood ow, (m^3/h m^3°C) is a distribution factor for vasomotor activity in muscle, a (°C) is the a erent thermal signal for the controlling system, and (m^3/h W) is a constant ranging from 0.2 to 3.5 m^3/h m^3°C for the six model cylinders. Eq. (7) was implemented into the controlling system of the original six-cylinder model and has been described elsewhere [6].

2.4. Numerical method

The numerical technique is a simple implicit method with central di erences. The spatial grid is 101 nodes in each half-cylinder. The time step begins at 3.6 s and is adjusted to each computed core temperature. The simulation program is written in FORTRAN and runs on PCs. For details, please refer to papers [6,18].

2.5. Goodness-of- t

A root mean square deviation (RMSD) was calculated between the time courses of observed and predicted values. The RMSD is de ned as [15,16]

$$\mathrm{RMSD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} d_i^2} \qquad (8)$$

where d_i is the di erence between the observed and predicted result, and n is the number of comparisons. Where data are scattered over time, the t is considered valid if the RMSD falls within the average standard deviations found for the observed data [15] or if the model prediction falls within one standard deviation of the subject mean [16]. Where single event comparisons are made (e.g., endpoint data), a paired t-test was applied with acceptance at the 0.05 level. Unless otherwise indicated, all mean results are reported with ±SD.

3. Results

The above constraints on shivering metabolism were integrated into the six-cylinder model [6] and validated against documented data. Data selected for the validation involved water immersion, air exposure, and a well-documented accident case report of water survival.

3.1. Water immersion

The experimental data used herein involved a group of 10 t, non-smoking subjects (3 females and 7 males) with a mean (±SD) age of 25.4 (±6.8) years, body mass of 73.5 (±13.8) kg, height of 1.76 (±0.1) m, and body fat of 24.8 (±6.2)% [10]. The subjects, wearing only bathing suits, were immersed to the upper chest level in cold water at a temperature of about 8–10°C in a seated position with arms out of water for 2–6.5 h. The stirred water was initially set at a temperature of 20°C, then lowered to approximately, 8°C over 15 min by adding ice.

The model was used to predict the thermal responses of the individual subjects to the water immersion. The inputs for each individual were height, weight, body fat percentage, age, maximal oxygen consumption, and water temperature. The mean measured core temperature (rectal) and mean skin temperature were compared with the predicted values at the end of the immersion. The results included the immersion time (termination was due to extreme discomfort) and metabolic rate, as summarized in Table 1.

Table 1 indicates that the mean of predicted results for the core and mean skin temperatures, and metabolic rate are within the range of the respective measured ±SD values. Paired t-tests indicated that there was no signi cant di erences between the measured and predicated core temperatures ($p = 0.35$) at the end of the immersion. The RMSD of the core temperature over the experimental period using 10 min interval data is 0.78°C, well within the maximum SD of 1.17°C for the observed

Table 1
Immersion time, mean measured and predicted core and mean skin temperatures, and metabolic rate at the end of the 8–10°C water immersion trials [10]

Subject	Time (min)	T_c (°C)		T_s (°C)		M (W)	
		Meas	Pred	Meas	Pred	Meas	Pred
1	380	35.0	35.0	14.2	14.3	444.0	411.8
2	250	34.7	35.1	16.8	14.7	327.0	314.4
3	240	34.9	34.6	12.1	14.4	340.0	261.4
4	200	34.3	35.5	18.5	16.0	323.0	335.9
5	190	35.5	35.2	17.1	15.8	322.0	298.0
6	180	34.7	34.8	15.9	15.0	302.0	246.0
7	170	34.2	35.1	14.8	15.5	447.0	397.0
8	160	33.1	34.6	19.3	15.6	404.0	378.2
9	130	35.7	35.2	17.5	16.2	345.0	351.7
10	120	36.3	35.5	16.7	15.1	342.0	253.7
Mean	202	34.8	35.1	16.3	15.3	359.6	324.8
SD	75	0.9	0.3	2.0	0.7	52.5	60.2

data. There was no signi cant di erence between the average measured and predicted mean skin temperatures at the end of the immersion ($p = 0.09$). The RMSD of the mean skin temperature over the experimental period was 1.25°C, also well within the maximum SD of 2.28°C for the observed data. The average predicted metabolic heat production was 34.8 W below the measured value at the end of the immersion ($p = 0.01$). However, this di erence would not be signi cant if the female subjects (i.e., subjects 3, 6, and 10) were excluded from the analysis. In that case, the average measured and predicted metabolic rates for the 7 remaining male subjects are 373.1 ± 57.0 and 355.3 ± 42.4 W, respectively ($p = 0.08$), and the RMSD of 75.0 W for the metabolic rate is within the maximum SD of 141.0 W for the observed values.

Figs. 2 and 3 show the measured ±SD and predicted core temperatures and metabolic rates, respectively, during the course of the immersion. The predicted values fall within the SD of the measured values over most of the immersion, but there were biases in the predictions that were revealed by a residual analysis. The correlation between ($T_{c\_pred} - T_{c\_meas}$) and T_{c_meas} using all the data ($n = 212$) is $18.2 - 0.50\, T_{c\_meas}$ ($r = 0.79$). That is, the model tends to over and under predict T_c for T_{c_meas} less and greater than 36.1°C, respectively. Similarly, the correlation between ($M_{pred} - M_{meas}$) and M_{meas} is $121.5 - 0.49 \cdot M_{meas}$ ($r = 0.68$). In this case, the model tends to over and under predict M for M_{meas} less and greater than 250.8 W, respectively. The tendency of an overall underprediction of the metabolic rate is attributed to the poor t of the female response, as already noted and discussed later.

3.2. Air exposure

The experimental data used herein involved a group of 9 healthy males of 1.77 (±0.06) m in height, 74.3 (±11.4) kg body mass, and 14 (±3)% body fat [17]. The subjects, wearing only shorts, were seated and exposed to 5°C air at a wind speed of about 1.0 m/s. Predictions were made for

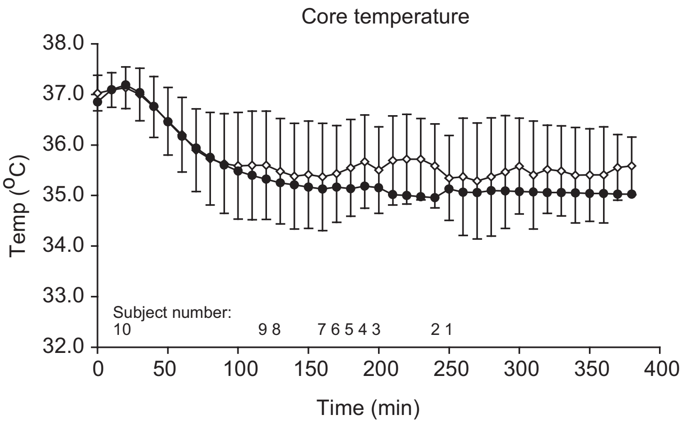


Fig. 2. Comparison of the measured (◇) mean ±SD and predicted (•) core temperatures for the 8–10°C immersion study [10].

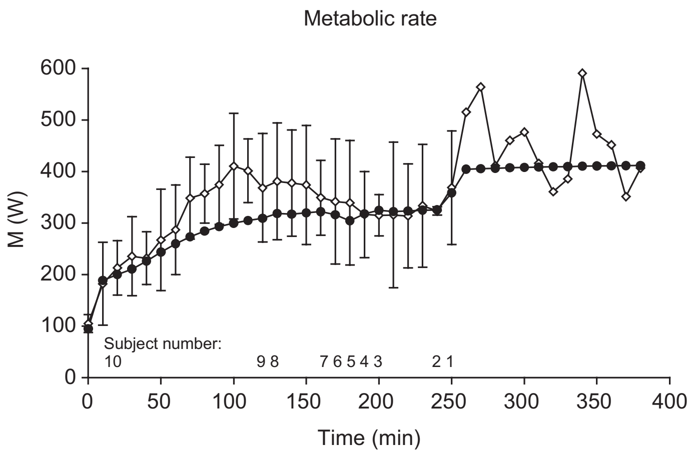


Fig. 3. Comparison of the measured (◇) mean ±SD and predicted (•) metabolic rates for the 8–10°C immersion study [10].

the average subject since individual characteristics were not reported. Further, the current model assumed a default value for $M_{\text{shiv,max}}$ of 4.5 x resting metabolic rate for $M_{\text{shiv,max}}$, as $V_{O_2\text{max}}$ was not measured.

Table 2 summarizes the comparison between the observed and predicted results. The core temperature approaches the lower end of the range of the measured core temperatures, the metabolic rate approaches the upper end of the range of the measured metabolic rates while the skin temperature is underpredicted. Considering that the seated subjects would not have experienced a streamline wind exposure, as less than half of their bodies faced the wind, predictions were made assuming a lesser wind of 0.5 m/s on the entire body surface. In this case, the predicted core temperature, skin temperature and metabolic rate fall within the SD of the measured values.

Table 2
Measured (±SD) and predicted core and mean skin temperatures, and metabolic rate for a group of 9 subjects after 3 h of 5°C air exposure [17]

	T_c (°C)	T_s (°C/h)	M (W/m^2)
Measured	36.47 (±0.81)	−3.88(±0.48)	145.0 (±45.0)
Predicted at 1 m/s wind	35.70	−4.67	190.0
Predicted at 0.5 m/s wind	35.88	−4.19	180.5

Table 3
Casualty characteristics and observed and predicted survival time (ST in h)

No	Age (yrs)	Height (m)	Mass (kg)	BF (%)	Obs ST	Pred ST
1	62	1.78	91	26.0	38	26.5[a]
2	63	1.83	83	18.4	14	14.25
3	35	1.80	86	21.6	12	18.25
4	56	1.68	73	17.0	11	10.0
5	45	1.64	68	15.0	9	7.25

[a]Casualty wore a wet suit whereas prediction assumed a nude condition [4].

3.3. Accidental water immersion

The accidental data used herein involved a group of 5 individuals who were immersed in 16.7°C water after their dive vessel capsized [4]. The 5 casualties clung to a wooden door, one (No. 1) clad in a full wet suit and the others only in pajamas. A rescue vessel arrived on the accident scene 38 h later and found only one survivor (No. 1); the others having slipped away at intervals chronicled by No. 1. Table 3 provides the basic characteristics of the casualties, and their recorded and predicted survival times (assuming nude immersions). The body fat percentage was calculated from the height and weight of the subject [18]. The predicted survival time was based on when the core temperature fell below 30°C. A paired t-test of the recorded vs. predicted survival times indicates no di erence ($p = 0.64$) between the two times for the four casualties that were the most severely exposed (i.e., No. 1 was excluded from the paired t-test since this individual had worn a wet suit that the model presently cannot account for).

4. Discussion

The present new conceptual model for shivering intensity (Fig. 1) combines a shivering predictive model [7], a "glycogen-depletion" model [2], a shivering exhaustion model [5], and a model of maximal shivering intensity [8]. There is, however, some uncertainty regarding the validity of the "glycogen-depletion" model. The study by Tikuisis [10] concluded that the "glycogen-depletion" model was satisfactory as a mathematical construct for the prediction of shivering fatigue, but that the underlying physiological basis is questionable, as most recently acknowledged by Wissler [19]. Indeed, another recent study demonstrated that during prolonged low intensity shivering, the heat production is unequally shared among lipids (50%), muscle glycogen (30%), plasma glycogen (10%), and proteins (10%) [20].

Yet, the current model prediction for the four casualties of the dive vessel accident were quite reasonable, and con rmed the provisional applicability of the "glycogen-depletion" model as a useful mathematical construct. While the present model prediction of survival time is not more accurate than that reported by Van Dorn [4] using a much simpler approach, nor that of Tikuisis' model [21], it provides greater capability to simulate the complexity of the human thermal response to cold and potentially will enable greater insight into thermoregulatory processes, as emphasized below.

The human body regulates shivering heat production and vasomotor activities to maintain its heat balance. The goal is to keep the core warm and stable. There is no clear de nition of what constitutes the core, but it should compose the viscera in the torso, the brain, and the blood constituents [22]. While the shivering heat production in the extremities (i.e., legs and arms) is bene cial to the maintenance of the core temperature during cold water immersion, this bene t may be o set for the following reasons: (1) the heat conduction from the extremities to the core is minimal due to the low-heat conductivity of tissues; (2) the temperature of the venous blood returning from extremities to the core would be low, as the tissue temperature can be rapidly reduced due to its physical shape and size [23]; and (3) as shivering demands more blood ow to the muscle, the perfused muscle thereby facilitates heat conduction from deep tissues to surface, and is eventually lost to the ambient cold. Bristow et al. [23] measured the tissue temperatures at depths of 15, 30 and 45 mm from the skin surface in the upper and lower leg during $\sim$ a 1 h immersion in 8°C water. All the tissue temperatures varied from about 0.7°C (the deepest upper leg location) to 14°C (the shallowest lower leg location) below the core temperature of about 34°C at the end of the immersion. This indicates that net heat was transferred from the core to the leg, acting as a heat sink despite the heat generated by the leg muscles during shivering. This concurs with the study by Bell et al. [24], who demonstrated that most of the increased metabolism (about 75%) was generated in the torso. Therefore, redistribution of blood from the extremities, and from the cutaneous and peripheral vasculature to more central locations (i.e. core) is a critical consideration of the present model that others ignore.

The predicted metabolic heat productions of the three females in the water immersion study (i.e., subjects 3, 6 and 10) were well below their measured values. While there is usually no gender di erences in thermal responses to environments except for the e ect of menstrual cycle phase [25,26], the reason for the above anomaly may likely be related to the female subjects having quite high body fat percentages ranging from 28.6% to 33.6%. Although it is necessary to consider the body fat in the prediction of metabolic rate [27], Eq. (1) seems to overemphasize the impact of the adiposity on the shivering heat production for people with markedly high body fat percentage. A recent study [10] attributed the underestimation of Eq. (1) for females to inappropriate weighting coe cients and/or too great an attenuation of the shivering response due to body fatness. Moreover, the metabolic rates per lean body weight (LBW) of these female subjects were between 7.18 and 8.39 W/kg LBW whereas that for male subjects were between 5.06 and 7.54 W/kg LBW, suggesting there is di erence of the metabolic rate per LBW between males and females. McArdle et al. [28] also demonstrated that such di erences exist during 1 h-immersion tests in 20°C, 24°C, and 28°C water. However, whether this gender di erence contributes to e ective metabolic rate requirement per LBW needs to be studied further.

There are two possible reasons why the predicted core temperature of the air exposure subjects tended to be lower than the measured one. First, as the subjects were seated on a nylon-webbed lawn chair, their exposure to the wind was not uniform across the entire body, as assumed by the model. This would result in a lower net rate of heat removal from the body than predicted by the model, leading to a smaller decrease in core temperature. Second, the measured core temperature at the end of 3 h of exposure might have actually been lower than reported since one of the subject's test was terminated at 151 min due to his core temperature dropping below the preset lower limit of 35.0°C [17]. Regarding the mean skin temperature, it is possible that the 12-point weighting system used for measurement overestimated the actually rate of temperature decrease for the entire body surface. Indeed, Haslam and Parsons [15] found that model predictions were less accurate under windy vs. calm conditions at an environmental temperature below 5°C.

Overall, the comparison of the model predictions against the observations from the experimental data and the accidental case report indicate close and reasonable agreement. However, further work is required to remove biases in these predictions, as revealed by the residual analysis. While individual characteristics of age, height, weight, body fat, and V_{O_2max} are presently implemented, additional e orts must be directed to identify several other factors, for instance the state of acclimatization and the fat content of the torso, that might further improve the predictability and applicability of the model.

5. Summary

In this study, a multi-segmental mathematical model has been developed for predicting shivering and thermoregulatory responses during long term cold exposure. The foundation for this model is a previous six-cylinder dynamic model of human temperature regulation [6] which was validated for heat and cold stress, various exercise loads, and for various clothing ensembles, but only for limited durations. The present model incorporates new knowledge on shivering thermogenesis, including the control and maximal limits of its intensity, inhibition due to a low core temperature, and prediction of endurance time. The model also takes into account individual characteristics of age, height, weight, % body fat, and maximum aerobic capacity. The model was validated against three di erent cold test conditions, one involving 10 subjects immersed in 8–10°C water for 2 to 6.5 h, a second group of 9 subjects exposed to 5°C air for 3 h, and a case report consisting of 5 casualties from a shipboard accident following immersion in 16.7°C water for up to 38 h. The predictions of the core and mean skin temperatures, shivering response, and/or survival times were found to be in good agreement with the observations.

Acknowledgements

We thank Dr. M. Yokota and Dr. Robert Wallace for statistical consultation. Part of this study was nished when the rst author was a research associate at the Laboratory for Exercise and Environmental Medicine University of Manitoba Canada.

The views, opinions, and/or ndings contained in this report are those of the authors and should not be construed as an o cial Department of the Army position, policy, or decision unless so designated by other o cial documentation.

References

[1] J.S. Hayward, J.D. Eckerson, Physiological responses and survival time-prediction for humans in ice-water, Aviat. Space Environ. Med. 55 (1984) 206–211.
[2] E.H. Wissler, Mathematical simulation of human thermal behavior using whole body models, in: A. Shitzer, R.C. Eberhart (Eds.), Heat Transfer in Medicine and Biology, Plenum Press, New York, 1985, pp. 325–373.
[3] P. Tikuisis, Prediction of the thermoregulatory response for clothed immersion in cold water, Eur. J. Appl. Physiol. 59 (1989) 334–341.
[4] W.G. Van Dorn, Thermodynamic model for cold water survival, J. Biomed. Eng. 122 (2000) 541–544.
[5] P. Tikuisis, Predicting survival time for cold exposure, Int. J. Biometeorol. 39 (1995) 94–102.
[6] X. Xu, J. Werner, A dynamic model of the human/clothing/environment-system, Appl. Human Sci. 16 (1997) 61–75.
[7] P. Tikuisis, G.G. Giesbrecht, Prediction of shivering heat production from core and skin temperatures, Eur. J. Appl. Physiol. 79 (1999) 221–229.
[8] D. Eyolfson, P. Tikuisis, X. Xu, G. Weseen, G. Giesbrecht, Measurement and prediction of maximal shivering intensity in human, Eur. J. Appl. Physiol. 84 (2001) 100–106.
[9] T.H. Benzinger, Heat regulation: homeostasis of central temperature in man, Physiol. Rev. 49 (1969) 671–759.
[10] P. Tikuisis, D.A. Eyolfson, X. Xu, G.G. Giesbrecht, Shivering endurance and fatigue during cold water immersion in humans, Eur. J. Appl. Physiol. 87 (2002) 50–58.
[11] D.R. Pendergast, The e ect of body cooling on oxygen transport during exercise, Med. Sci. Sports Exerc. 20 (1988) 171–176.
[12] M.B. Ducharme, W.P. VanHelder, M.W. Radomski, Cyclic intramuscular temperature uctuations in the human forearm during cold-water immersion, Eur. J. Appl. Physiol. 63 (1991) 188–193.
[13] Y.S. Park, D.R. Pendergast, D.W. Rennie, Decrease in body insulation with exercise in cool water, Undersea Biomed. Res. 11 (1984) 159–168.
[14] A. Veicsteinas, G. Ferretti, D.W. Rennie, Super cial shell insulation in resting and exercising men in cold water, J. Appl. Physiol. 52 (1982) 1557–1564.
[15] R.A. Haslam, K.C. Parsons, Using computer-based models for predicting human thermal responses to hot and cold environments, Ergonomics 37 (1994) 399–416.
[16] K.K. Kraning, R.R. Gonzalez, A mechanistic computer simulation of human work in heat that accounts for physical and physiological e ects of clothing, aerobic tness, and progressive dehydration, J. Therm. Biol. 22 (1997) 331–342.
[17] A.L. Vallerand, P. Tikuisis, M.B. Durcharme, I. Jacobs, Is energy substrate mobilization a limiting factor for cold thermogenesis? Eur. J. Appl. Physiol. 67 (1993) 239–244.
[18] X. Xu, Optimierung des Systems Mensch/Kuhlanzug bei Hitzearbeit, Clausthal-Zellerfeld: Papier iege, 1996.
[19] E.H. Wissler, Probability of survival during accidental immersion in cold water, Aviat. Space Environ. Med. 74 (2003) 47–55.
[20] F. Haman, F. Peronnet, G.P. Kenny, D. Massicotte, C. Lavoie, C. Scott, J.-M. Weber, E ect of cold exposure on fuel utilization in humans: plasma glucose, muscle glycogen, and lipids, J. Appl. Physiol. 93 (2002) 77–84.
[21] P. Tikuisis, Prediction of survival time at sea based on observed body cooling rate, Aviat. Space Environ. Med. 68 (1997) 441–448.
[22] P. Tikuisis, Heat balance precedes stabilization of body temperature during cold water immersion, J. Appl. Physiol. 95 (2003) 89–96.
[23] G.K. Bristow, M.D. Sessler, G.G. Giesbrecht, Leg temperature and heat content in humans during immersion hypothermia and rewarming, Aviat. Space Environ. Med. 65 (1994) 220–226.
[24] D.G. Bell, P. Tikuisis, I. Jacobs, Relative intensity of muscles contraction during shivering, J. Appl. Physiol. 65 (1990) 2336–2342.

[25] R. Gonzalez, L.A. Blanchard, Thermoregulatory responses to cold transients: e ects of menstrual cycle in resting women, J. Appl. Physiol. 85 (1998) 543–553.
[26] P. Tikuisis, I. Jacobs, D. Moroz, A.L. Vallerand, L. Martineau, Comparison of thermoregulatory response between men and women immersed in cold water, J. Appl. Physiol. 89 (2000) 1403–1411.
[27] P. Tikuisis, R.R. Gonzalez, R.A. Oster, K.B. Pandolf, Role of body fat in the prediction of the metabolic response for immersion in cold water, Undersea Biomed. Res. 15 (1988) 123–134.
[28] W.D. McArdle, J.R. Magel, T.J. Gergley, Thermal adjustment to cold-water exposure in resting men and women, J. Appl. Physiol. 56 (1984) 1565–1571.

Xiaojiang Xu received his B.Sc. (1983) and M.Sc. (1986) in Mechanical Engineering from the Beijing University of Aeronautics & Astronautics in China, and his Ph.D. in Mechanical Engineering from the Ruhr University Bochum, Germany. He was a senior research engineer in the Environmental Physiology Unit, Simon Fraser University from 1999 to 2002, and a post-doctoral research associate at the Laboratory for Exercise and Environmental Medicine, University of Manitoba from 1996 to 1999. He is currently a scientist in the Biophysics and Biomedical Modeling Division, US Army Research Institute of Environmental Medicine, Natick, MA. His research interests include thermoregulatory modeling, mechanisms of heat transfer in humans and clothing, brain cooling mechanisms, and personal cooling systems.

Peter Tikuisis received his B.Sc. (1975) and M.Sc. (1976) in Physics from the University of Waterloo, and his Ph.D. (1981) in Mechanical Engineering from the University of Toronto. He has been a defence scientist at DRDC, Toronto since 1975, and currently holds associate professorships at the Universities of Toronto and Waterloo. His work involves theoretical, analytical, and experimental research to develop mathematical models of human physiological responses to environmental stressors. His expertise covers decompression sickness, carbon monoxide intoxication, and thermoregulation. He has developed a prediction model of survival time for cold exposure presently used by Search and Rescue, and he was involved in the development of the new wind chill index with Environment Canada. His current interest has also expanded to the e ects of stressors and/or enhancements on human performance, speci cally target detection and marksmanship.

Richard R. Gonzalez received his B.S. from the University of Texas in 1961, his M.S. from the University of San Francisco in 1966 and his Ph.D. in Physiology and Biophysics from the University of California, Davis in 1970. He is currently the president of Bio-Tor, Inc., Sports Biophysics Consultants, Sherborn, MA. He was Chief, Biophysics and Biomedical Modeling Division, US Army Research Institute of Environmental Medicine, Natick, MA from May 1983 to December 2003. He held an Adjunct Professor, Biological Modeling Department, Washington State University, Pullman, WA from May 1998 to December, 2003. He was an Associate Fellow & Professor of Bioengineering, J.B. Pierce Foundation, Yale School of Medicine from June 1972 to April 1983. His research interests include thermoregulatory modeling, mechanisms of heat transfer, and physical factors in environments.

Gordon G. Giesbrecht received his B.P.E. (1985), his M.Sc. (1986), and his Ph.D. in Respiratory Physiology (1990) from the Department of Physiology, University of Manitoba. This was followed by one year of post-doctoral research training in the Department of Medicine, University of Calgary. He is currently a Professor in the Faculty of Physical Education and Recreation Studies, and the Department of Anesthesia, Faculty of Medicine, at the University of Manitoba. He is a Research A liate of the Health, Leisure and Human Performance Research Institute where he directs the Laboratory for Exercise and Environmental Medicine. His research interests cover human responses to exercise/work in extreme environments, pre-hospital care for human hypothermia, and human physical and mental performance in other stresses such as altitude (hypoxia) and diving (hypobaria).

Polisen

Bilaga - Skäligen misstänkt

Enhet	Diarienr
Region Syd, BINR 3 PO S Skåne	5000-K1548032-22

Skäligen misstänkt person		Personnr
Inkvist, Jasmine		19890204-4125
Identifierad	**Kontrollsätt**	**Kommentar**
Ja	Känd av polisanställd	

Polisen

Bilaga - Skäligen misstänkt

Enhet		Diarienr
Region Syd, BINR 3 PO S Skåne		5000-K1548032-22

Skäligen misstänkt person		Personnr
Inkvist, Thord Daniel		19801228-4058
Identifierad	**Kontrollsätt**	**Kommentar**
Ja	Känd av polisanställd	

Polisen

Personalia och dagsbotsuppgift

Utskriftsdatum
2023-11-07

Namn	Personnummer
Inkvist, Thord Daniel	19801228-4058

Tilltalsnamn	Kallas för	Öknamn	Kön
Daniel			Man

Födelseförsamling	Födelselän	Födelseort utland
Landskrona		

Medborgarskap	Hemvistland	Telefonnr
Sverige		0729626839: Mobiltelefon

Postadress
Storgatan 14 C
241 62 Löberöd

Folkbokföringsort
Löberöd

Föräldrars/Värdnadshavares namn och adress (beträffande den som inte fyllt 20 år)

Utbildning

Yrke / Titel

Arbetsgivare

Telefonnr

Anställning (nuvarande och tidigare)

Arbetsförhet och hälsotillstånd

Kompletterande uppgifter

Uppgiven inkomst	Bidrag	Hemmavarande barn under 18 år
200000	Bostadsbidrag 4000 SEK, barnbidrag x6	6

Försörjningsplikt	Skulder
Ja på 5 av barnen	350000

Förmögenhet
0

Kontroll utförd

Taxerad inkomst	Taxeringsår
297800	2021

Taxeringskontroll utförd av	Datum
Pa A.Hadzic	2022-12-27

Underrättelse/Delgivning jml RB 23:18a

Polisen

Enhet
Region Syd, BINR 3 PO S Skåne

Ärende

Diarienr
5000-K1548032-22

Underrättad av
Johansson, Petra

Gärning
Grov fridskränkning Fullbordat, Eslöv Eslöv, mellan 2020-04-01 00:00 och 2022-08-30

Grov misshandel Fullbordat, Storgatan 14 C Löberöd, mellan 2022-06-30 00:00 och 2022-12-24 05:00

Grov misshandel Fullbordat, Storgatan 14 C Löberöd, mellan 2022-11-01 00:00 och 2022-12-24 05:00

Grov misshandel Fullbordat, Storgatan 14 C Löberöd, mellan 2022-12-01 00:00 och 2022-12-24 05:00

Olaga frihetsberövande Fullbordat, Hasslerödsvägen 2 Eslöv, mellan 2020-04-01 00:00 och 2022-06-30 05:00

Olaga frihetsberövande Fullbordat, Storgatan 14 C Löberöd, mellan 2022-06-30 00:00 och 2022-12-24 05:00

Synnerligen grov misshandel Fullbordat, Storgatan 14 C Löberöd, mellan 2022-12-24 00:00 och 2022-12-24 05:00

Berörd person

Personnr
19890204-4125

Efternamn
Inkvist

Förnamn
Jasmine

Underrättelsesätt
Muntlig underrättelse

Delgiven info. om ev. förenklad delgivning
2023-02-01

Datum för muntlig underrättelse
2023-09-15

Yttrande senast (rådrum)
2023-10-27

Notering
Misstänkt har getts möjlighet att ta del av materialet från den slutförda utredningen (RB 23:18a § / FUK 12 §)

Resultat av slutunderrättelse
Erinran

Information gällande erinran
Se tilläggsprotokoll erinran

Försvarare

Namn
Gerleman, Ebba

Underrättelsesätt
Muntlig underrättelse

Datum för muntlig underrättelse	Yttrande senast (rädrum)
2023-09-15	2023-10-27

Notering
Tagit del digitalt

Resultat av slutunderrättelse
Erinran

Information gällande erinran
Se tilläggsprotokoll erinran

Underrättelse/Delgivning jml RB 23:18a

Polisen

Enhet
Region Syd, BINR 3 PO S Skåne

Ärende

Diarienr	Underrättad av
5000-K1548032-22	Johansson, Petra

Gärning
Grov fridskränkning Fullbordat, Eslöv Eslöv, mellan 2020-04-01 00:00 och 2022-08-31
Grov misshandel Fullbordat, Storgatan 14 C Löberöd, mellan 2022-06-30 00:00 och 2022-12-24 05:00
Grov misshandel Fullbordat, Storgatan 14 C Löberöd, mellan 2022-12-01 00:00 och 2022-12-24 05:00
Grov misshandel Fullbordat, Storgatan 14 C Löberöd, mellan 2022-11-01 00:00 och 2022-12-24 05:00
Olaga frihetsberövande Fullbordat, Hasslerödsvägen 2 Eslöv, mellan 2020-04-01 00:00 och 2022-06-30 05:00
Olaga frihetsberövande Fullbordat, Storgatan 14 C Löberöd, mellan 2022-06-30 00:00 och 2022-12-24 05:00
Synnerligen grov misshandel Fullbordat, Storgatan 14 C Löberöd, mellan 2022-12-24 00:00 och 2022-12-24 05:00

Berörd person

Personnr	Efternamn	Förnamn
19801228-4058	Inkvist	Thord Daniel

Underrättelsesätt	Delgiven info. om ev. förenklad delgivning
Muntlig underrättelse	2023-02-01

Datum för muntlig underrättelse	Yttrande senast (rädrum)
2023-09-15	2023-10-27

Notering
Misstänkt har getts möjlighet att ta del av materialet från den slutförda utredningen (RB 23:18a § / FUK 12 §)

Resultat av slutunderrättelse
Erinran

Information gällande erinran
Se tilläggsprotokoll erinran

Försvarare

Namn
Elvingsson, Anders

Underrättelsesätt
Muntlig underrättelse

Datum för muntlig underrättelse	Yttrande senast (rådrum)
2023-09-15	2023-10-27

Notering
Tagit del digitalt

Resultat av slutunderrättelse
Erinran

Information gällande erinran
Se tilläggsprotokoll erinran