

WORKCLIMATE 2.0  
TEMPERATURE ESTREME E IMPATTI SU SALUTE, SICUREZZA E PRODUTTIVITÀ AZIENDALE  
Strategie di intervento e soluzioni tecnologiche, informative e formative



**INAIL**  
ISTITUTO NAZIONALE PER L'ASSICURAZIONE  
CONTRO GLI INFORTUNI SUL LAVORO

## Sperimentazione delle giacche ventilate e valutazione delle performance

ing. Simona Del Ferraro

*INAIL*

*Dipartimento di Medicina, Epidemiologia, Igiene del Lavoro ed Ambientale  
Laboratorio di Ergonomia e Fisiologia*



Roma, 24 marzo 2026

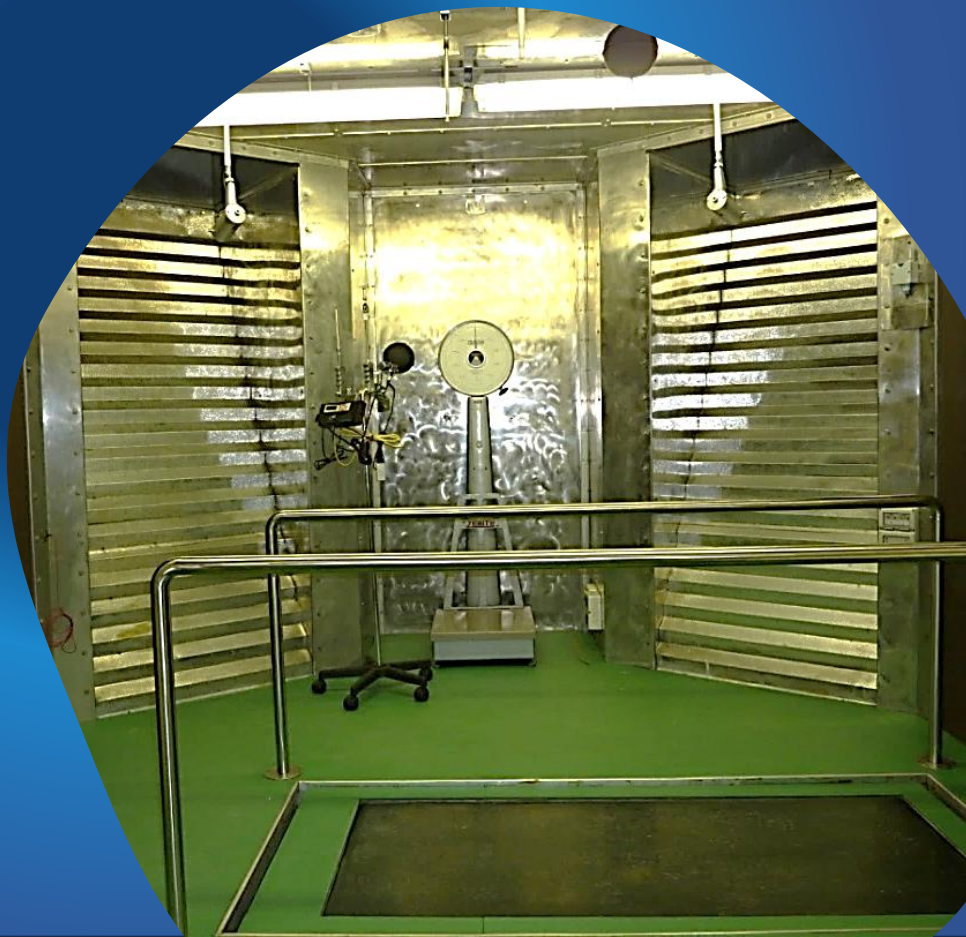


Manichino termico



## LABORATORIO DI ERGONOMIA E FISIOLOGIA

Camera climatica



## TECNOLOGIE INNOVATIVE....

....per il monitoraggio termofisiologico ed il  
raffreddamento del corpo

SMART-SHIRT



INAIL

PCB ISTITUTO PER I POLIMERI COMPOSITI E BIONOMATERIALI

ICOMATE

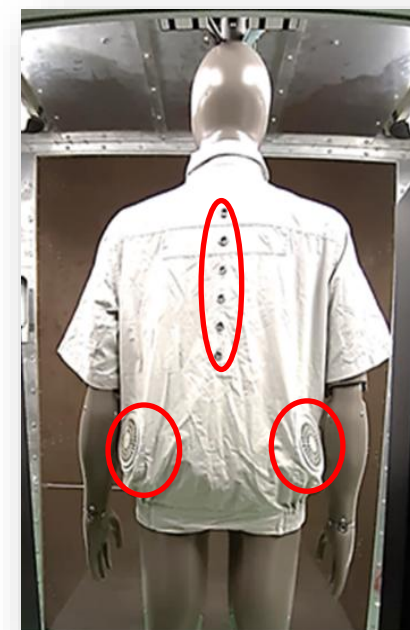
Istituto Clinico Scientifico Mangiari

....per il raffreddamento del corpo



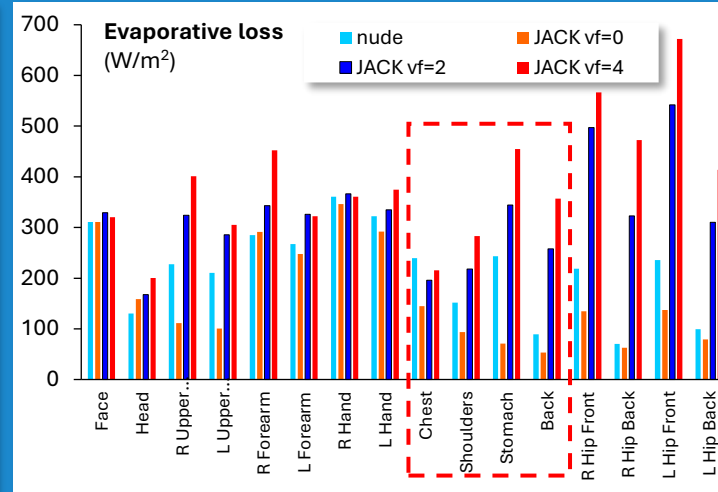
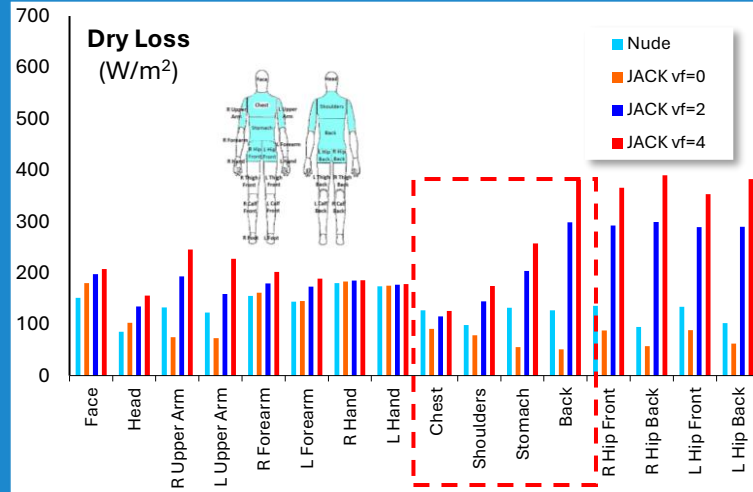
# La giacca ventilata testata in cantiere

- Strato più esterno in **cotone**
- Nella parte posteriore è presente un secondo strato a **rete in poliestere**
- **2 ventole di diametro 8 cm** ciascuna alimentata da una batteria agli ioni di Litio, con un voltaggio di 7.4V e capacità pari a 4400 mAh.  
Velocità delle ventole regolabile su **4 livelli**  
( $v=2=6$  l/min;  $v=4=12$  l/min)
- **6 aperture circolari aggiuntive** di diametro 1 cm sono presenti nella parte posteriore della giacca, poste a circa 4.5 cm di distanza (centro – centro)
- **2 tasche esterne e una zip** per tutta la lunghezza della giacca
- **Elastico** nella parte inferiore della giacca per far aderire la giacca nella zone dei glutei





## DRY E WET TEST



International Journal of Industrial Ergonomics 66 (2021) 103290

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: [www.elsevier.com/locate/ergon](http://www.elsevier.com/locate/ergon)

Cooling garments against environmental heat conditions in occupational fields: measurements of the effect of a ventilation jacket on the total thermal insulation

Simona Del Ferraro<sup>a,\*</sup>, Tiziana Falcone<sup>a,b</sup>, Marco Morabito<sup>c,d</sup>, Alessandro Messeri<sup>c,d</sup>, Michela Bonafede<sup>e</sup>, Alessandro Marinaccio<sup>e</sup>, Chuanshi Gao<sup>f</sup>, Vincenzo Molinaro<sup>g</sup>

Environmental Research 212 (2022) 113475

Contents lists available at ScienceDirect

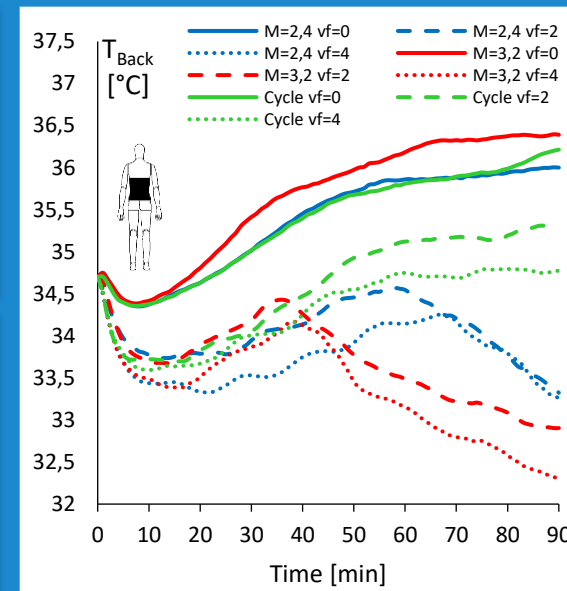
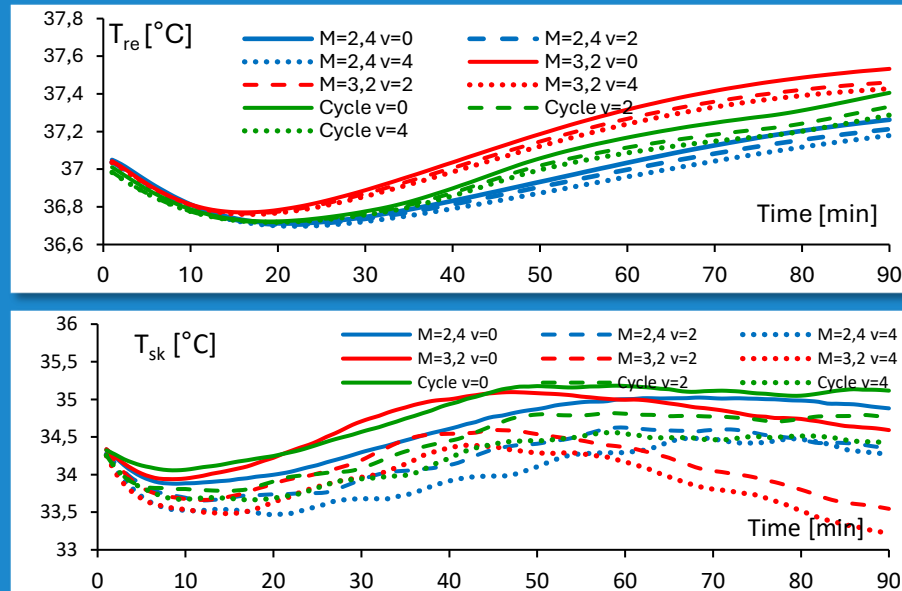
Environmental Research

journal homepage: [www.elsevier.com/locate/erres](http://www.elsevier.com/locate/erres)

A potential wearable solution for preventing heat strain in workplaces: The cooling effect and the total evaporative resistance of a ventilation jacket

Simona Del Ferraro<sup>a,\*</sup>, Tiziana Falcone<sup>a,b</sup>, Marco Morabito<sup>c,d</sup>, Alessandro Messeri<sup>c,d</sup>, Michela Bonafede<sup>e</sup>, Alessandro Marinaccio<sup>e</sup>, Chuanshi Gao<sup>f</sup>, Vincenzo Molinaro<sup>g</sup>

## TEST FISILOGICI



Contents lists available at ScienceDirect

Journal of Thermal Biology

journal homepage: [www.elsevier.com/locate/jtherbio](http://www.elsevier.com/locate/jtherbio)

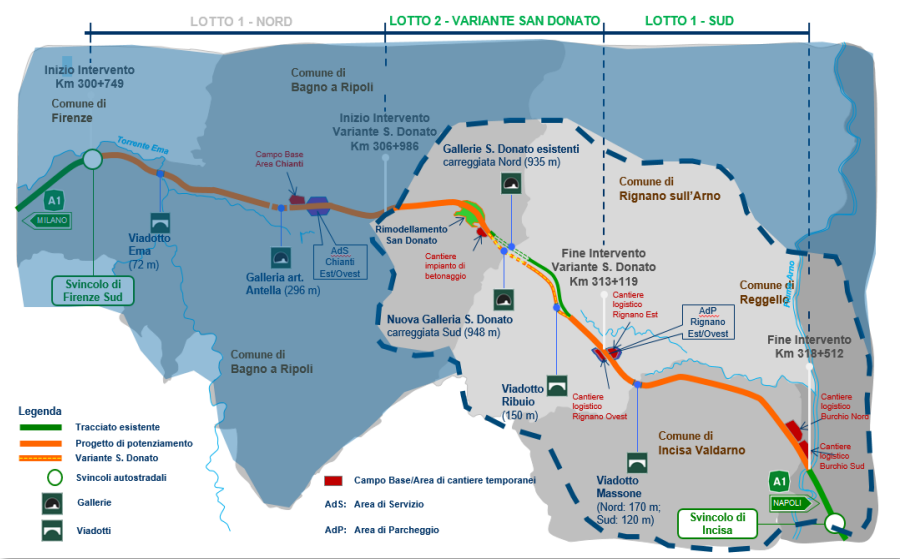
Mitigating heat effects in the workplace with a ventilation jacket: Simulations of the whole-body and local human thermophysiological response with a sweating thermal manikin in a warm-dry environment

Simona Del Ferraro<sup>a,\*</sup>, Tiziana Falcone<sup>a,b</sup>, Marco Morabito<sup>c,d</sup>, Michela Bonafede<sup>e</sup>, Alessandro Marinaccio<sup>e</sup>, Chuanshi Gao<sup>f</sup>, Vincenzo Molinaro<sup>g</sup>

Legend: 30th (solid line), 60th (dashed line), 90th (dotted line).

ampliamento alla 3° corsia dell'autostrada A1

Tratto Firenze sud - Incisa Valdarno



2024

2025

Durata test=30 min

Durata test=60 min

7 soggetti

6 soggetti

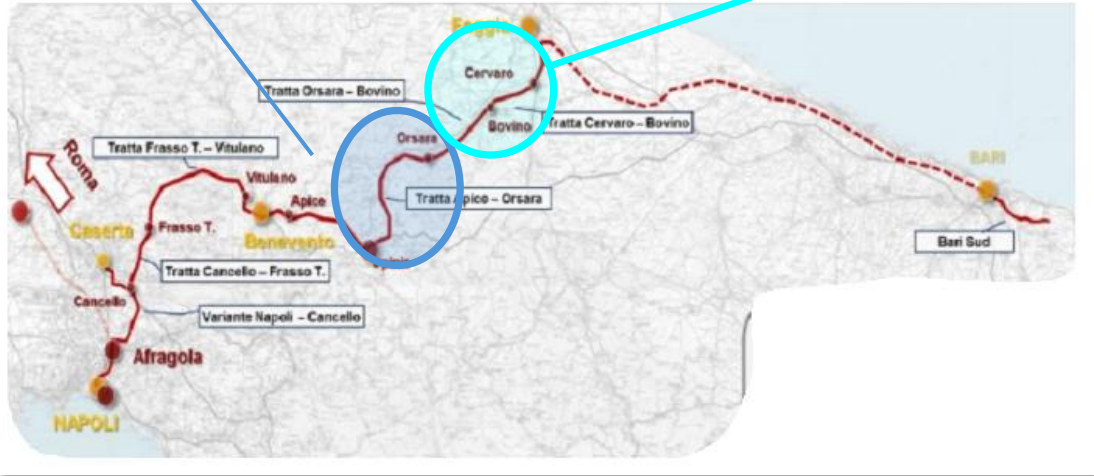
13 soggetti arruolati

20 soggetti arruolati

Linea ferroviaria AV/AC Napoli – Bari

Lotto Orsara Bovino  
Area Precast 01

Raddoppio tratta Apice Orsara  
Lotto Hirpinia Orsara  
Area CO.02



2024

2025

Durata test=30 min

Durata test=60 min

4 soggetti

3 soggetti

7 soggetti arruolati

# Setup sperimentale

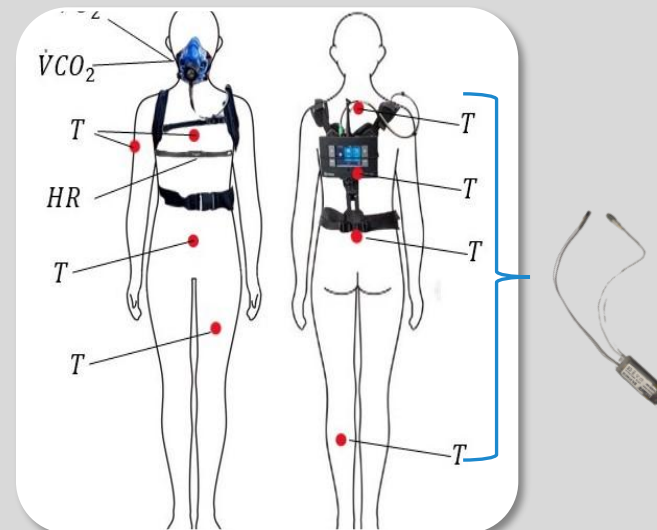
- Misure di parametri ambientali
- Misure di parametri termofisiologici
- Questionari

## Misure parametri ambientali



- Temperatura dell'aria
- Velocità dell'aria
- Umidità relativa
- Temperatura del globo
- Temperatura bulbo umido a ventilazione naturale
- Calcolo della temperatura media radiante

## Misure parametri termofisiologici



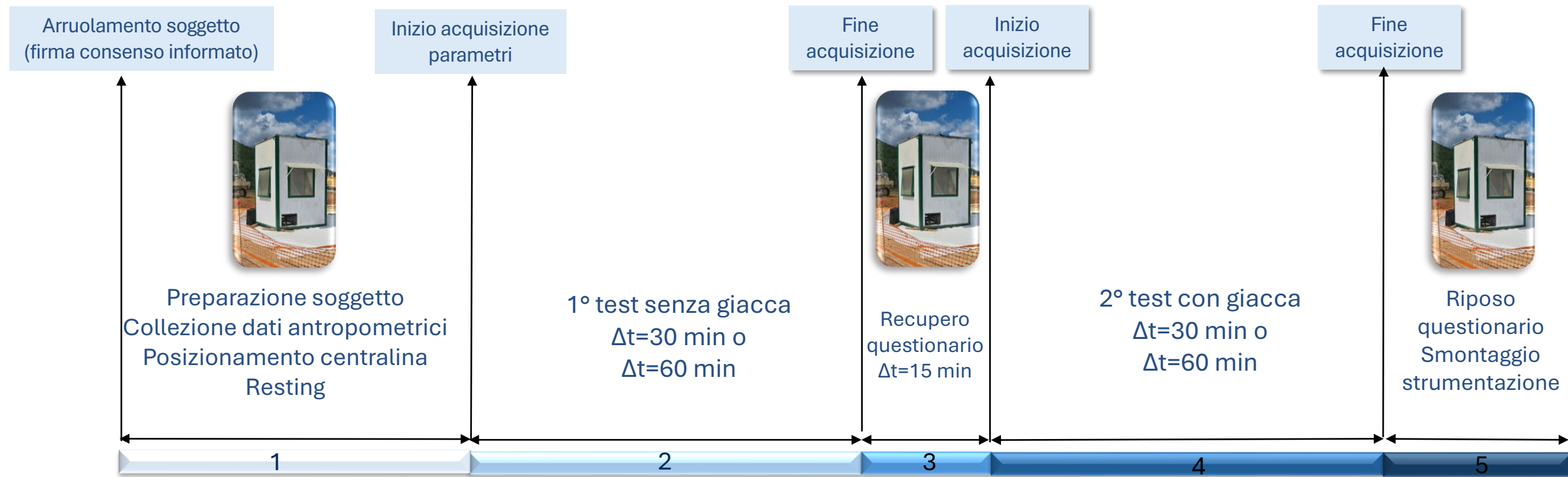
- Consumo di ossigeno e produzione di anidride carbonica
- Frequenza cardiaca
- Temperatura della pelle in 8 specifici punti del corpo

## Questionari



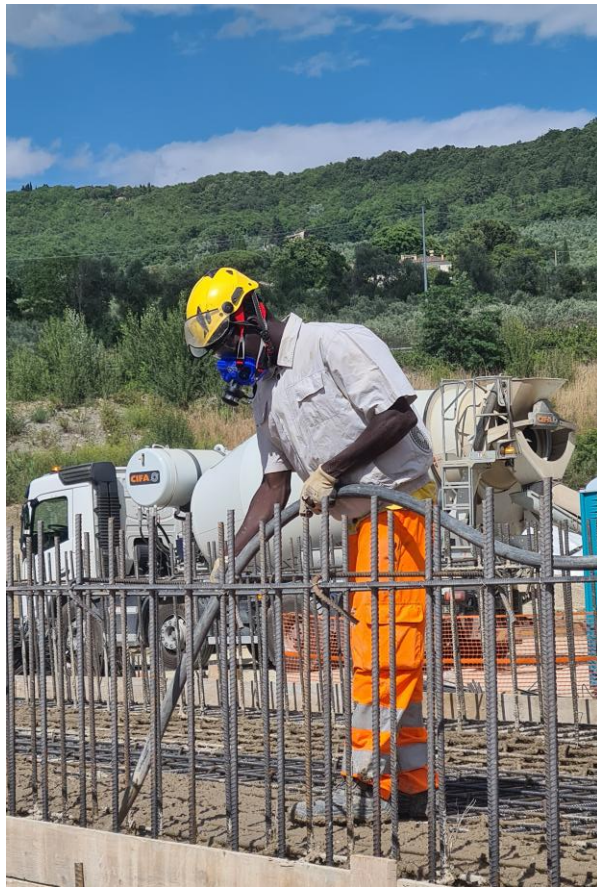
- Sforzo percepito
- Sintomi percepiti (sudorazione, stanchezza, sete, vertigini, spossatezza, confusione, difficoltà a respirare)
- Sensazione termica globale e locale
- Usabilità ed accettabilità

# Il protocollo sperimentale





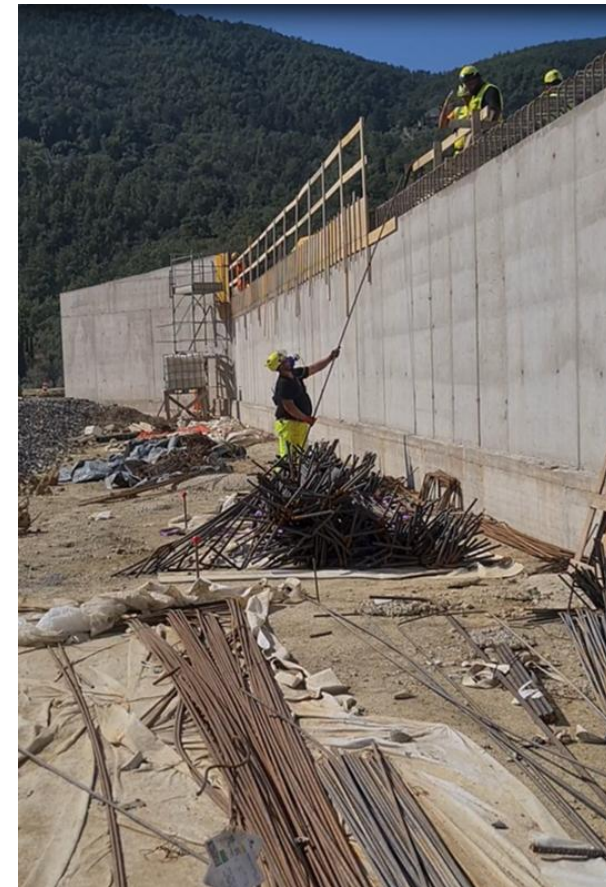
Legatura dei ferri di armatura di una platea o di una parete



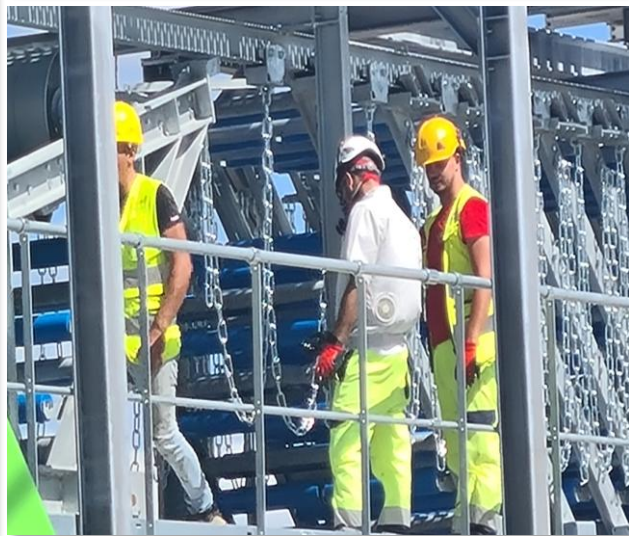
Vibrazione del calcestruzzo appena gettato



pulitura del calcestruzzo uscito dai casseri dopo il getto



Movimentazioni di ferri lunghi di armatura



INCIL

Montaggio struttura metallica per lo  
smaltimento del materiale scavato dalla TBM

armatura platea di fondazione delle vasche di  
approvvigionamento acqua a servizio della TBM

# Le attività monitorate

Ergonomia dell'ambiente termico - Determinazione del metabolismo energetico

UNI EN ISO 8996

FEBBRAIO 2022

Consumo di  
ossigeno

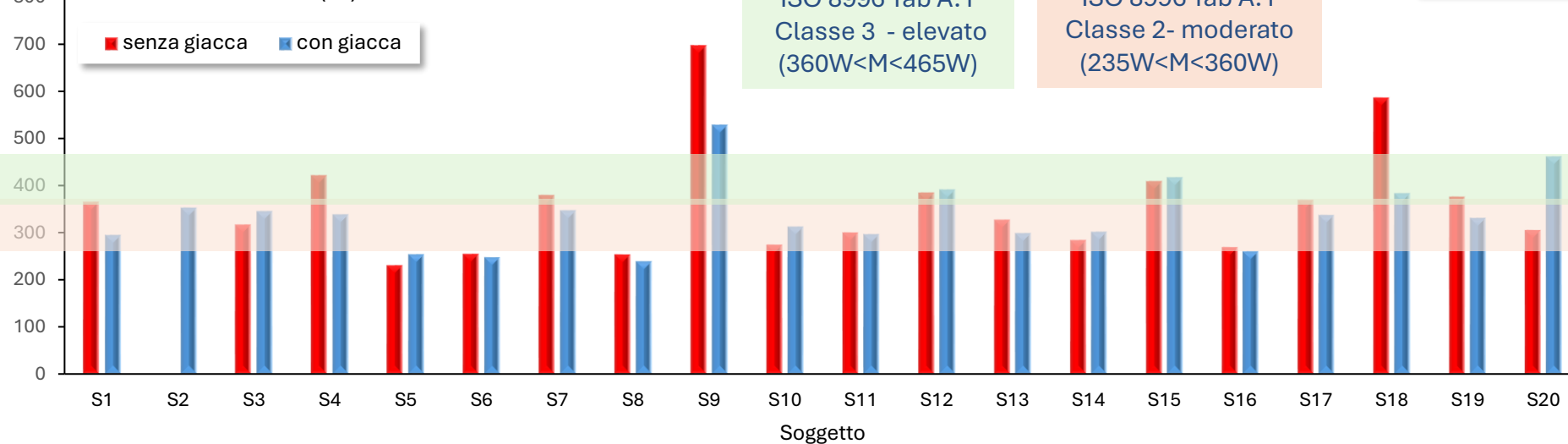
Produzione di  
anidride  
carbonica

$$EE = f(RQ)$$

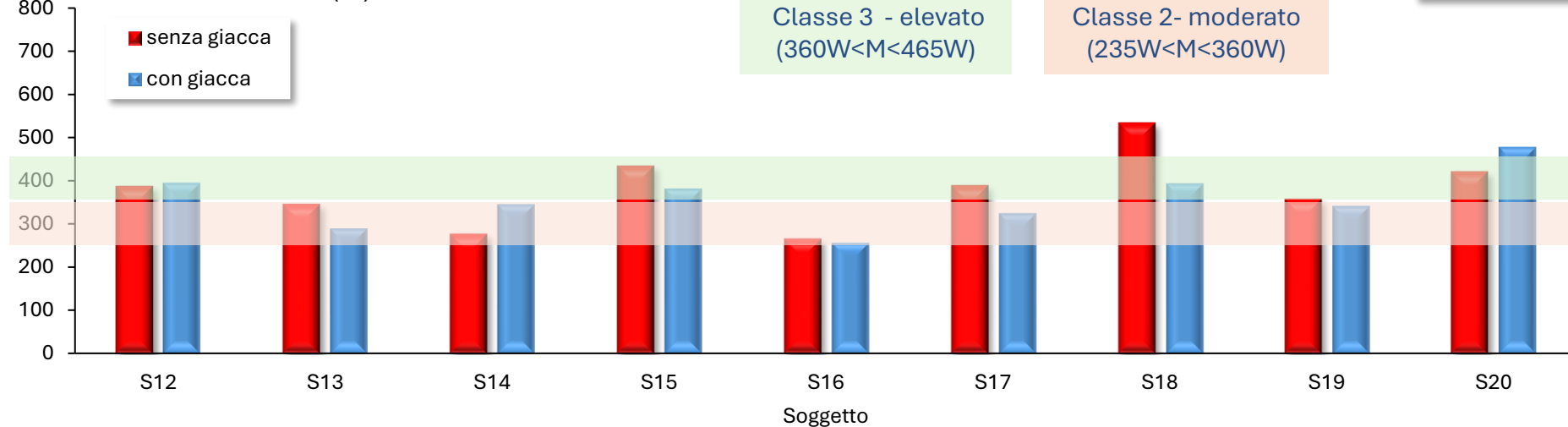
Metabolismo

INAIL

Metabolismo medio (W)

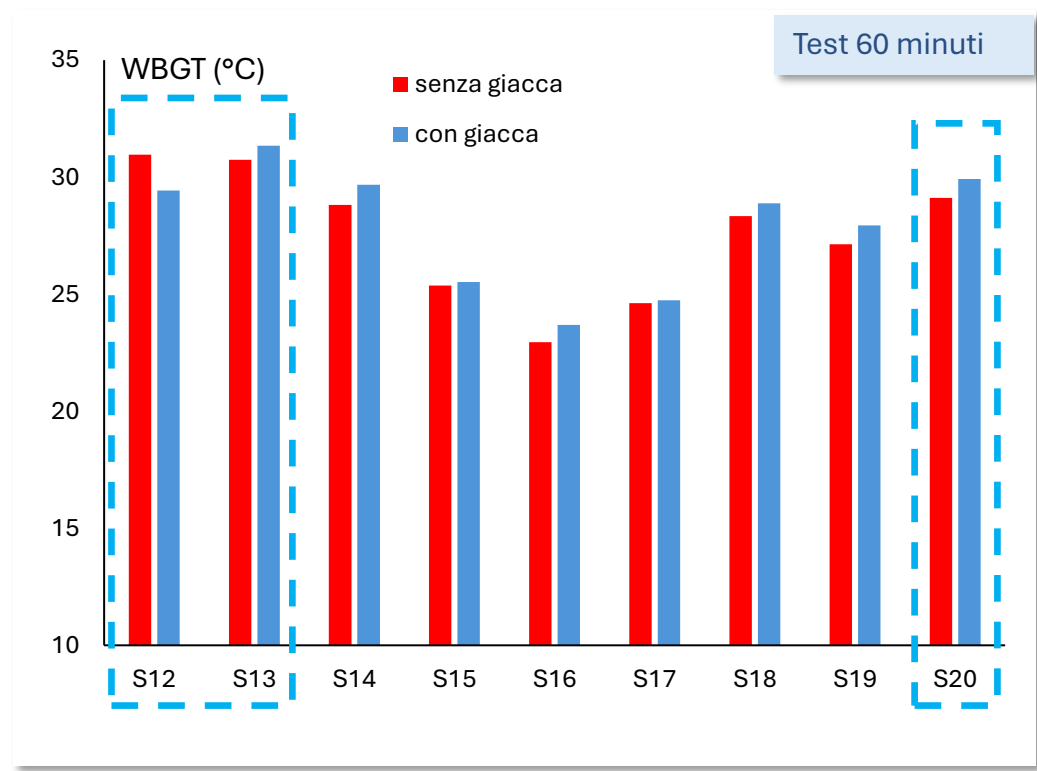
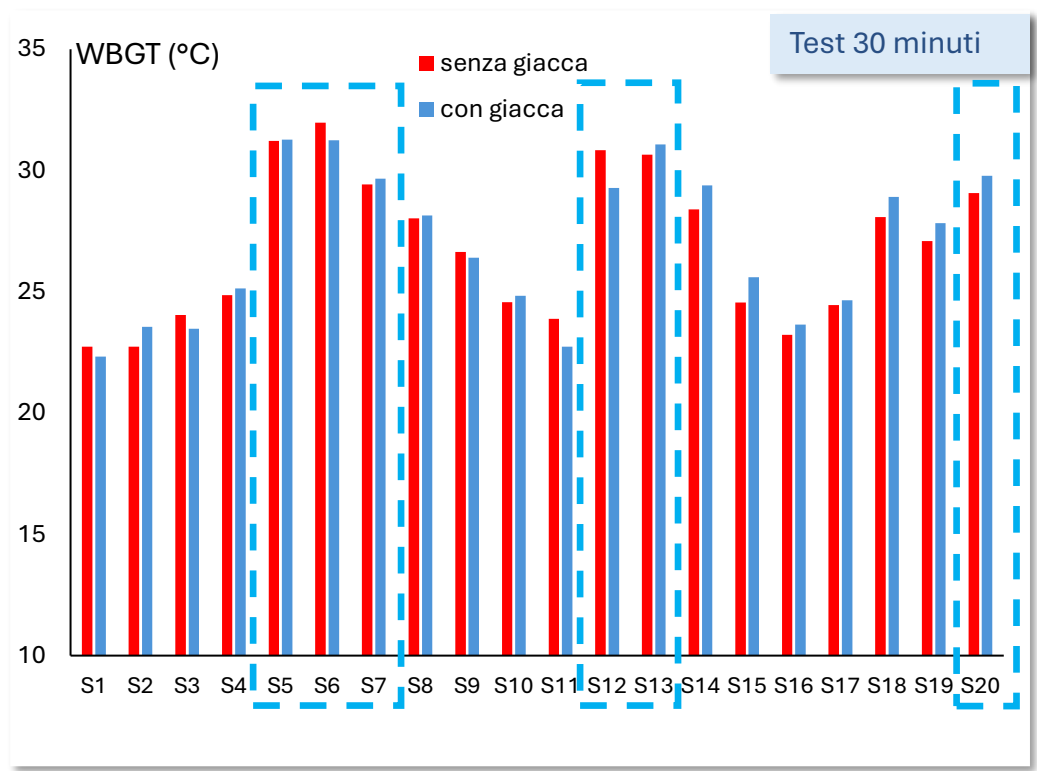


Metabolismo medio (W)



# Lo scenario d'esposizione

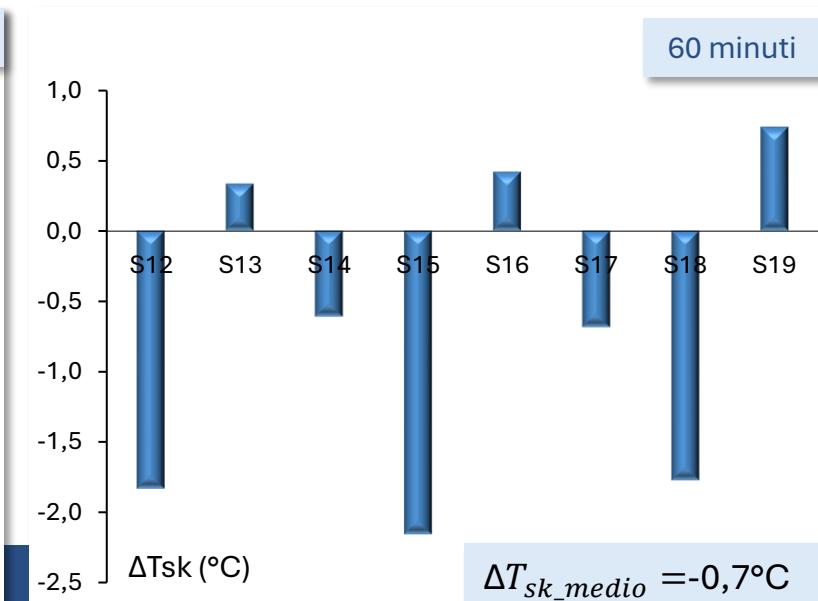
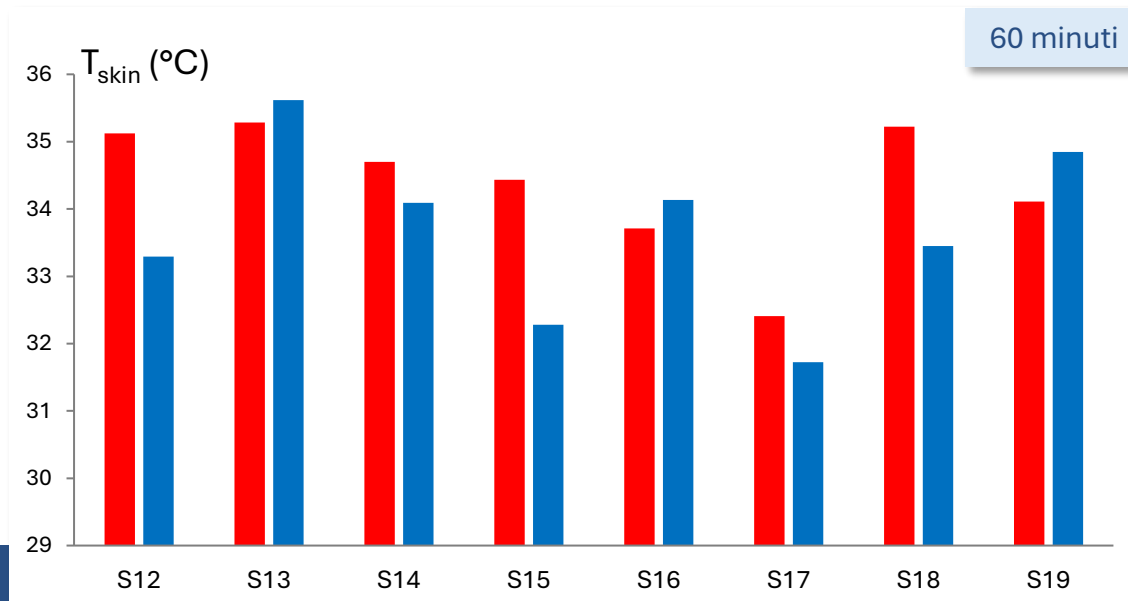
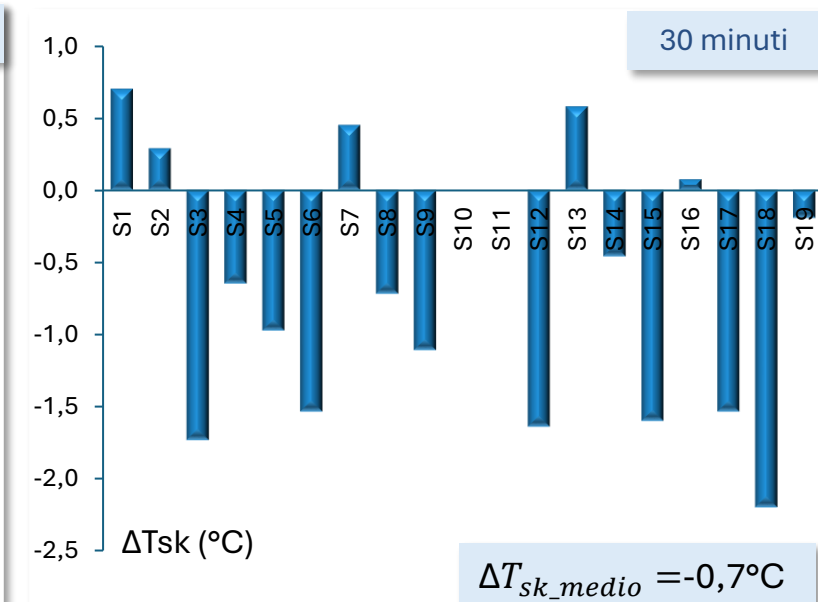
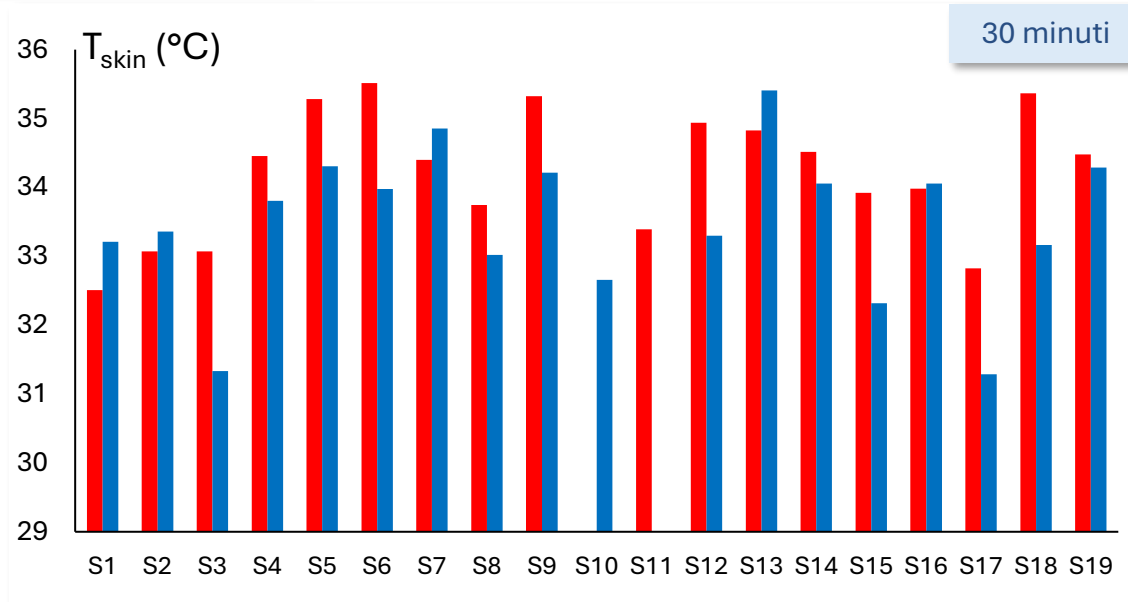
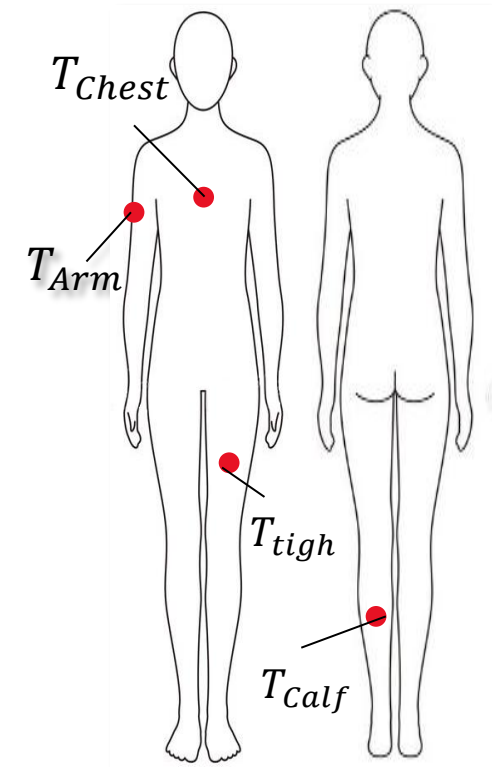
$$WBGT = 0.7 \cdot t_{nw} + 0.3 \cdot t_g + 0.1 \cdot t_a$$



# Temperatura media della pelle

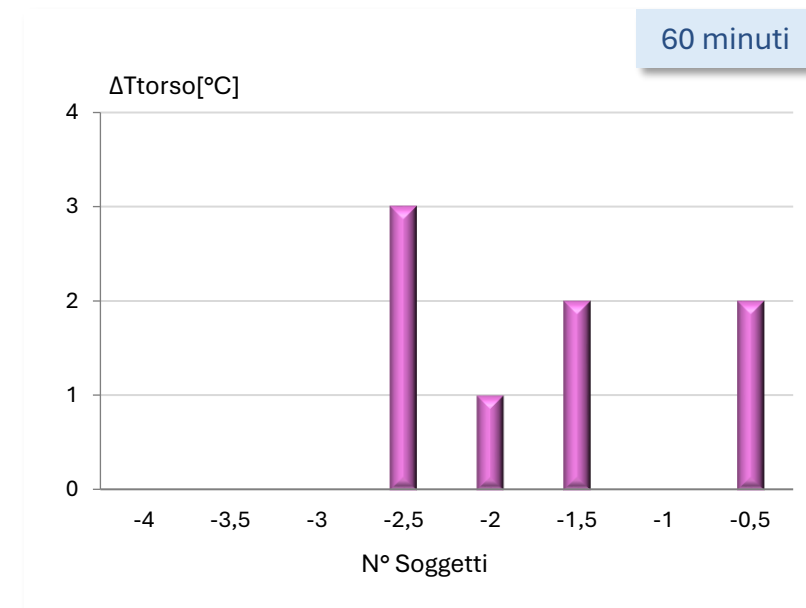
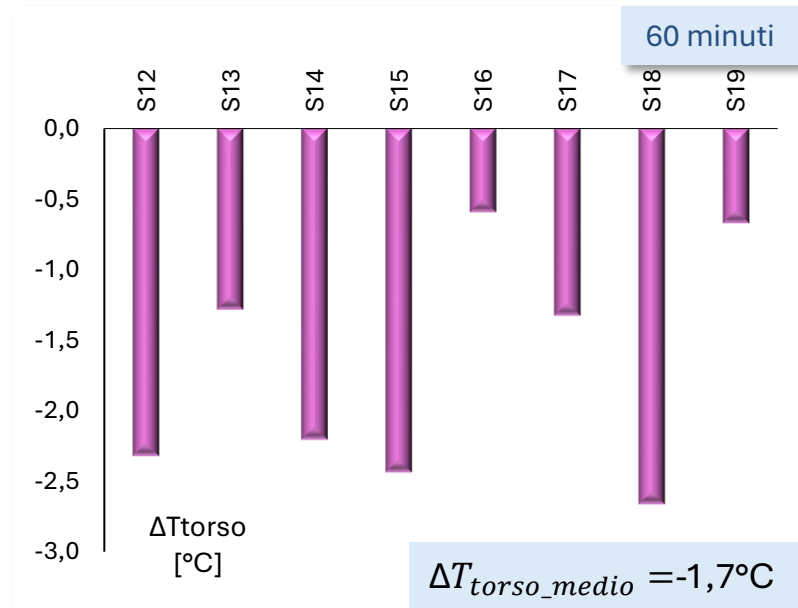
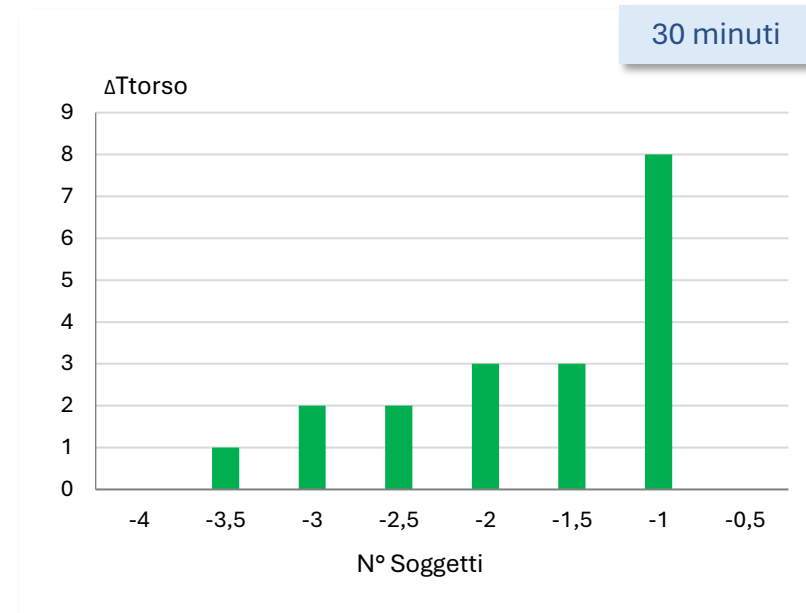
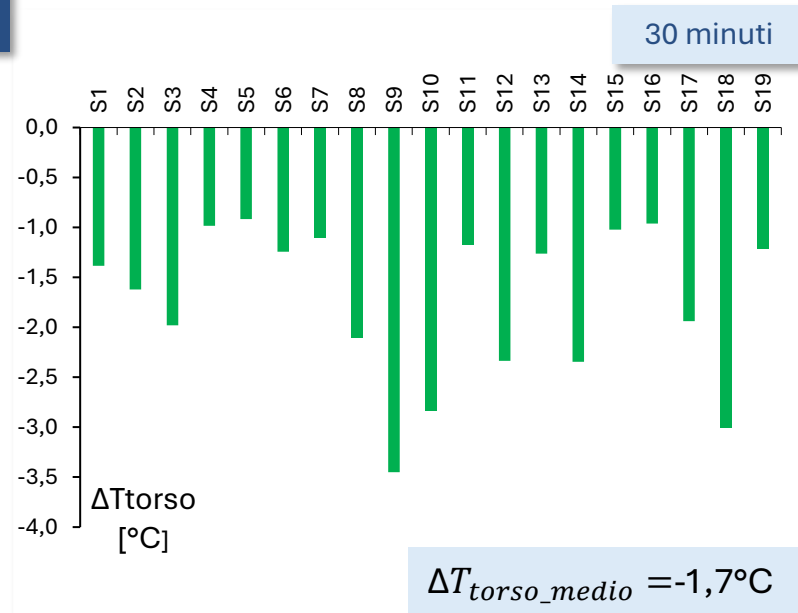
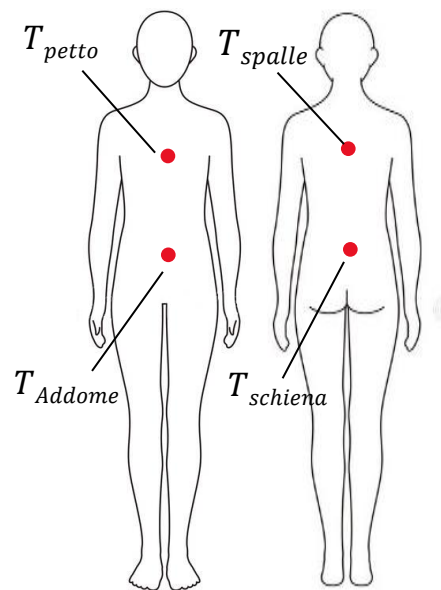
$$T_{sk} = (0.3 \cdot T_{Chest} + 0.3 \cdot T_{Arm} + 0.2 \cdot T_{tigh} + 0.2 \cdot T_{calf})$$

(Ramanathan, 1964)

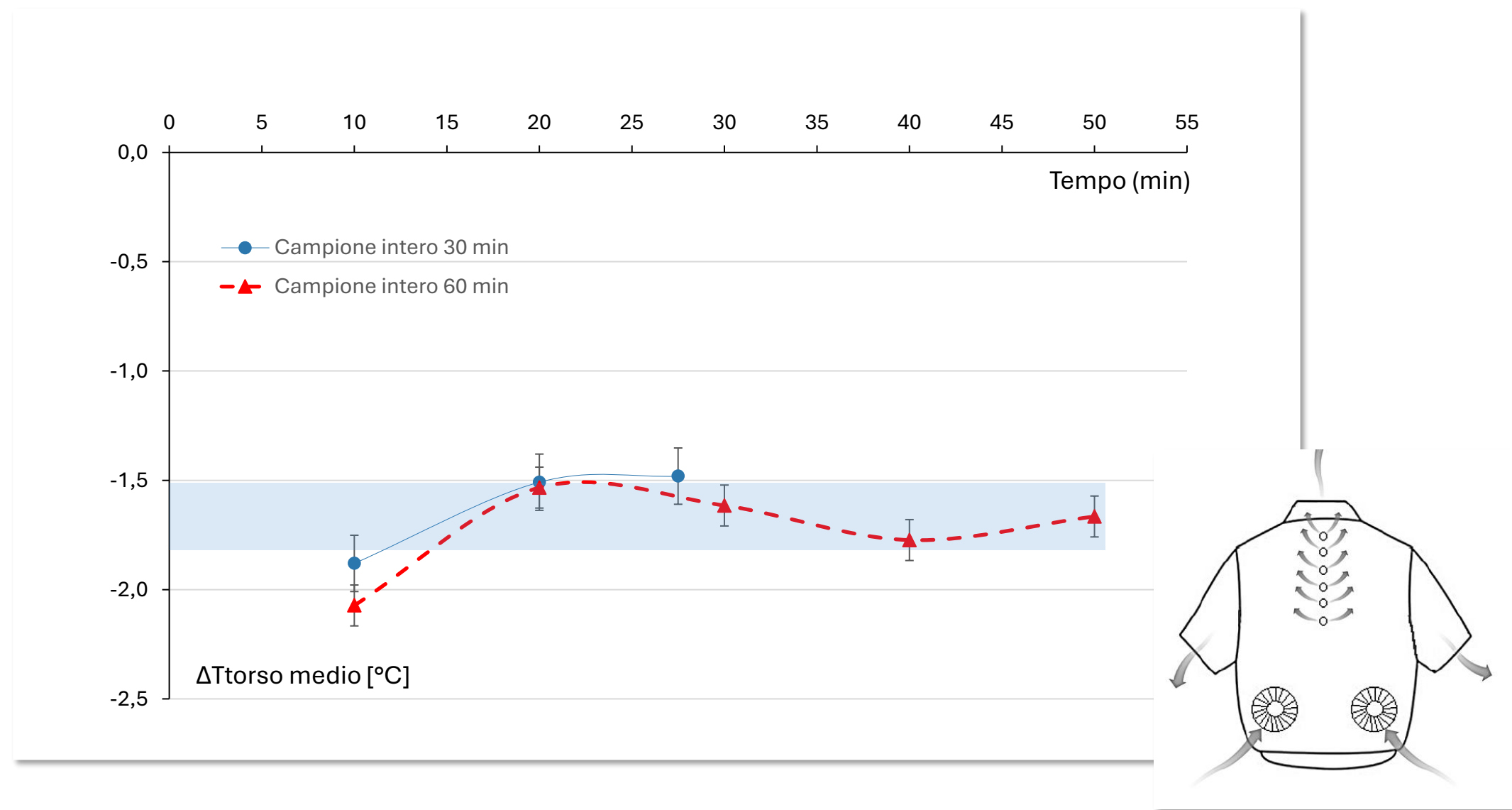


# Temperatura media del torso

$$T_{torso} = (T_{Chest} + T_{abdomen} + T_{Shoulders} + T_{Back})/4$$

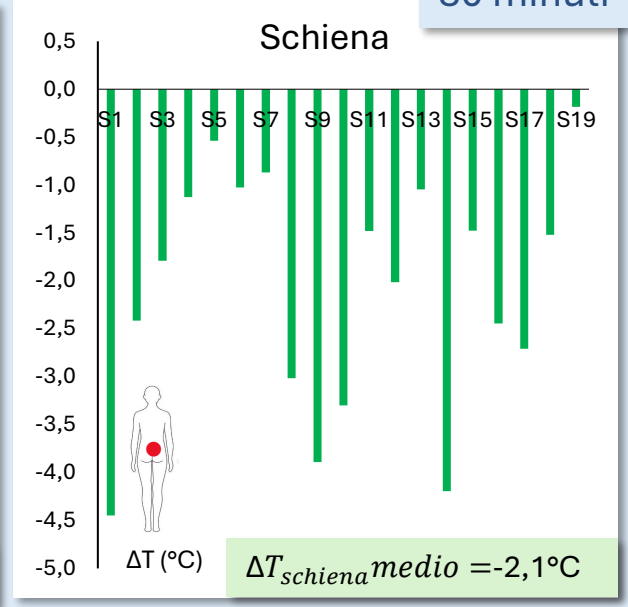
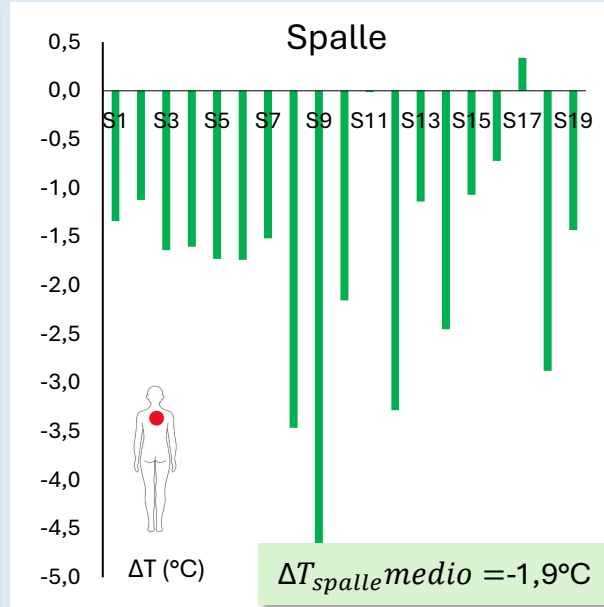
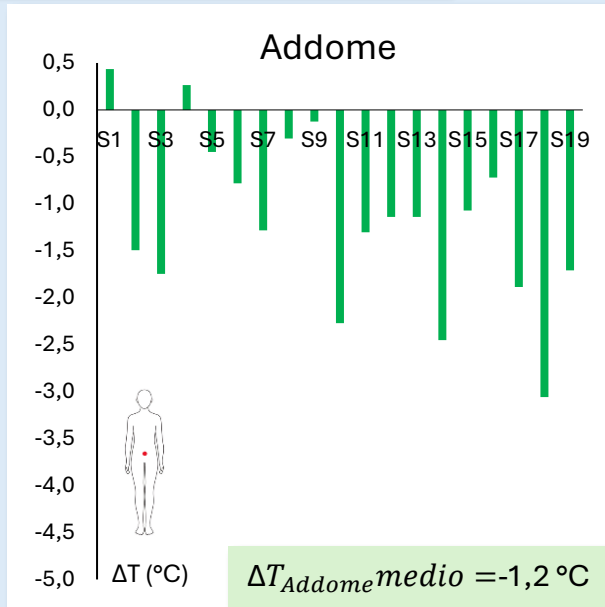
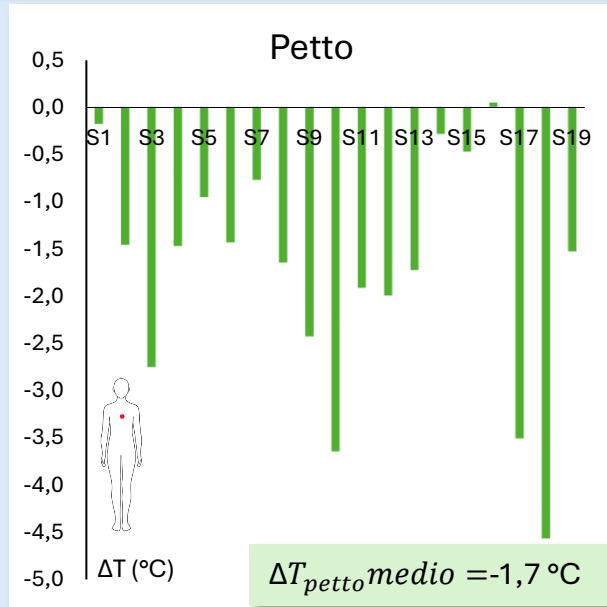


# Andamento nel tempo di $\Delta T_{\text{torso medio}}$

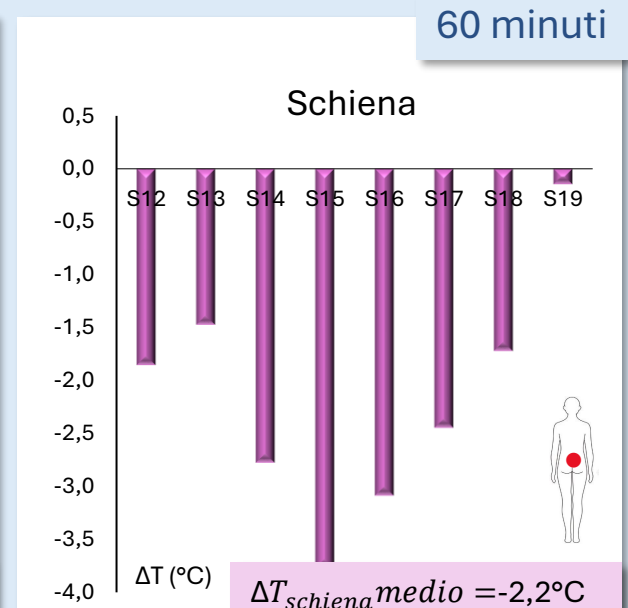
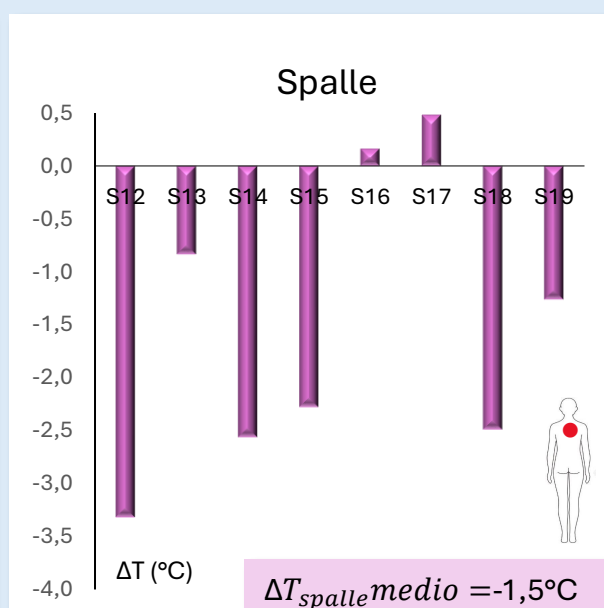
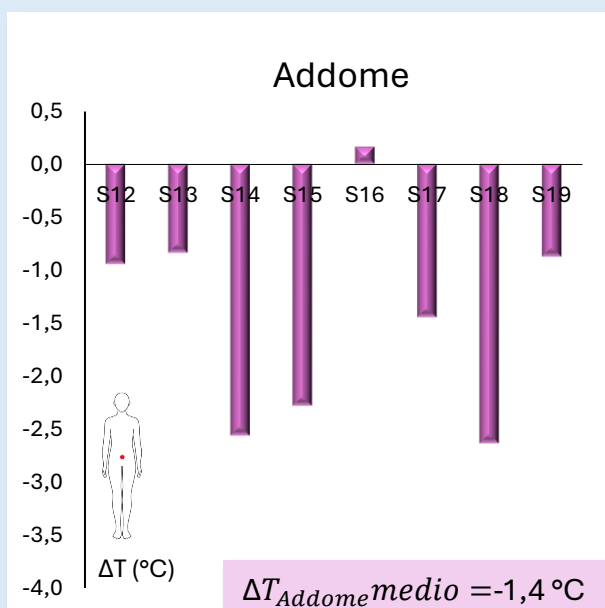
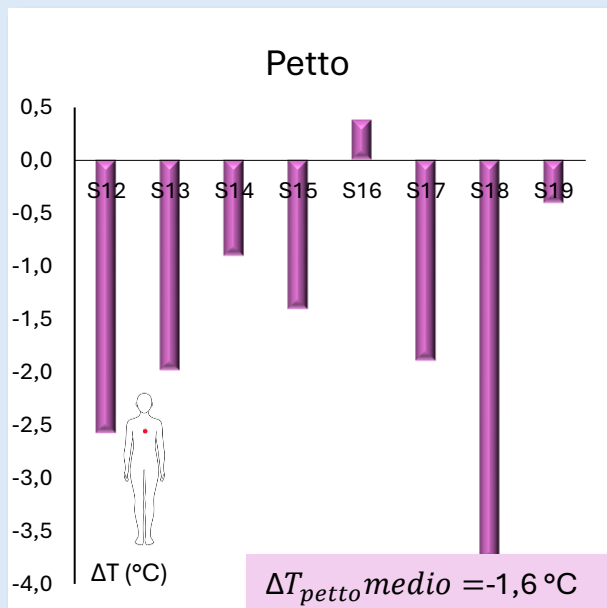


# le temperature delle 4 zone del tronco

30 minuti

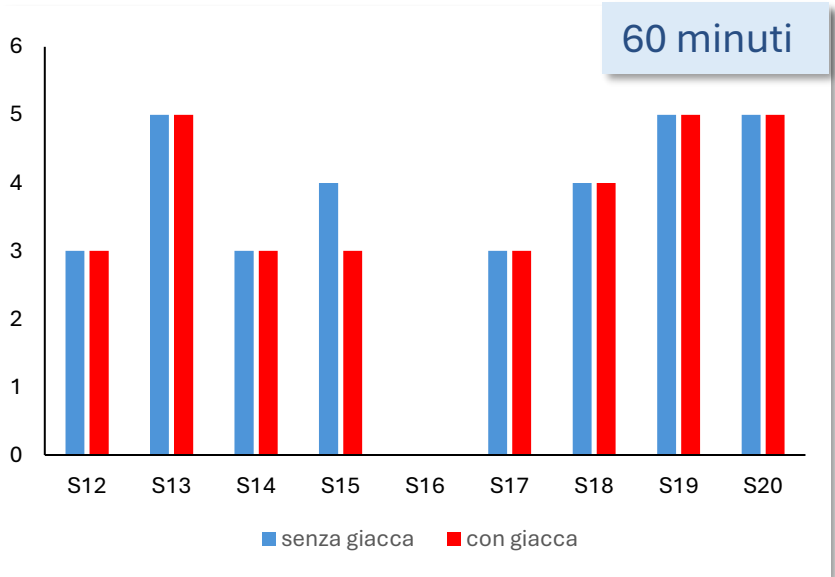
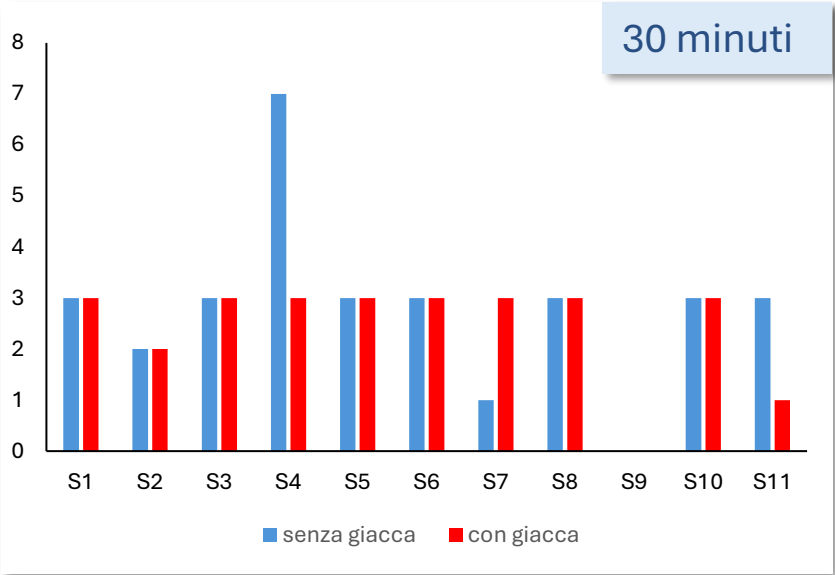


60 minuti



# Il questionario: sforzo percepito

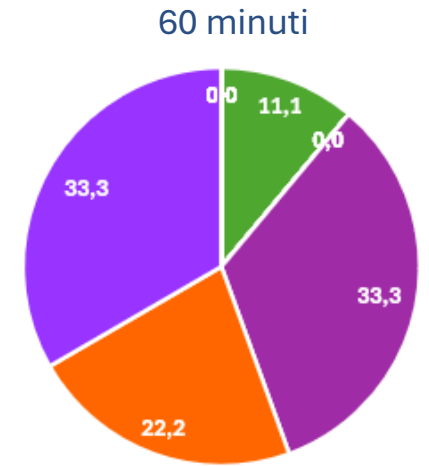
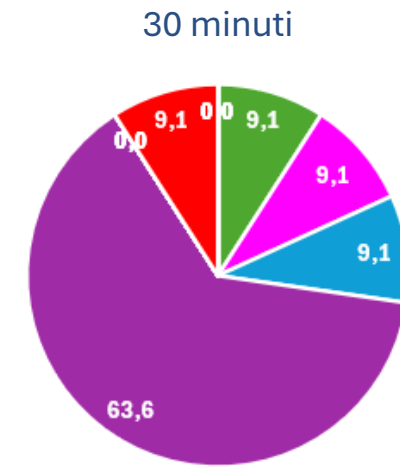
Durante l'attività che hai effettuato che intensità di sforzo hai percepito?



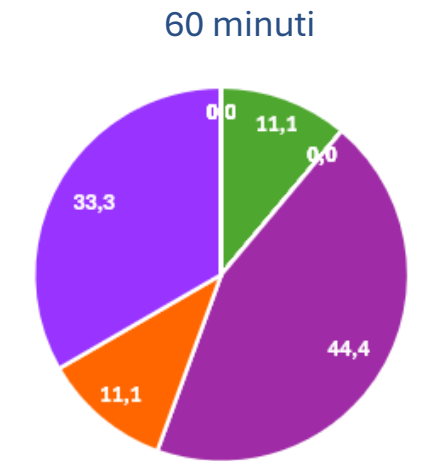
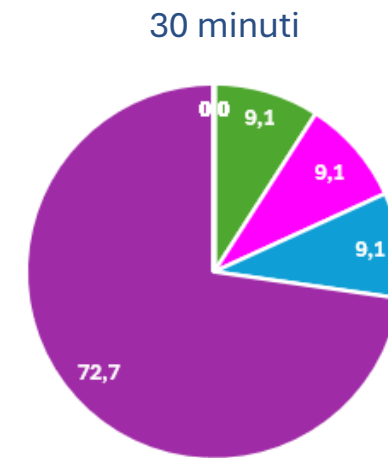
## Scala di Borg



## Senza giacca



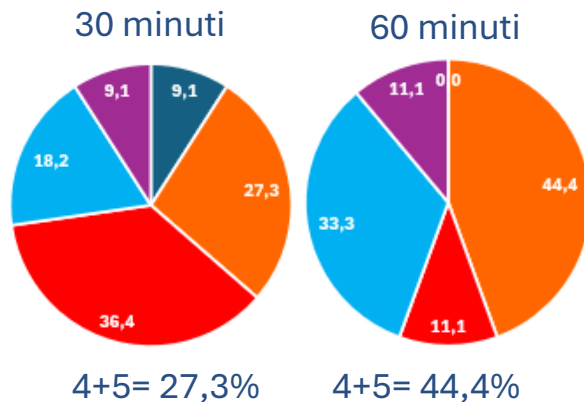
## Con giacca



### Sudorazione

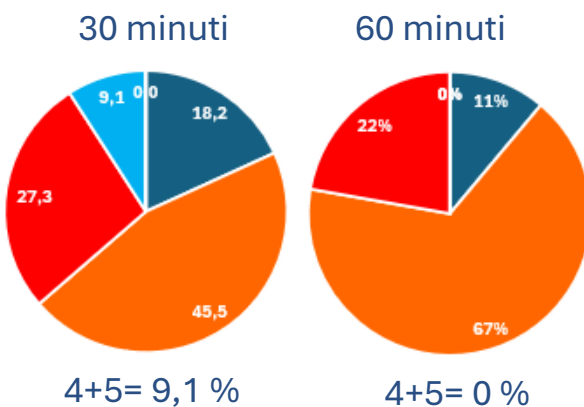
Senza giacca

- 1 Nessuna o molto leggera
- 2 Leggera
- 3 Moderata
- 4 Intensa
- 5 Molto intensa



Con giacca

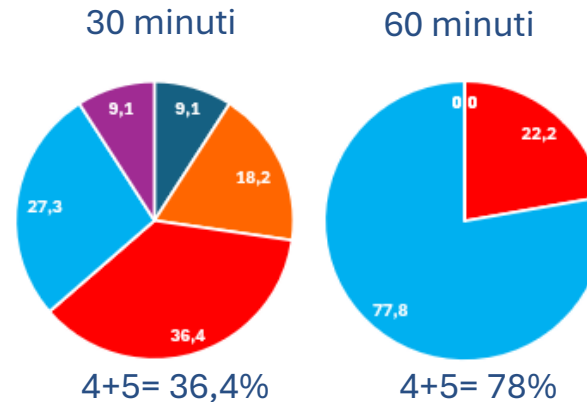
- 1 Nessuna o molto legger.
- 2 Leggera
- 3 Moderata
- 4 Intensa
- 5 Molto intens.



### Sete

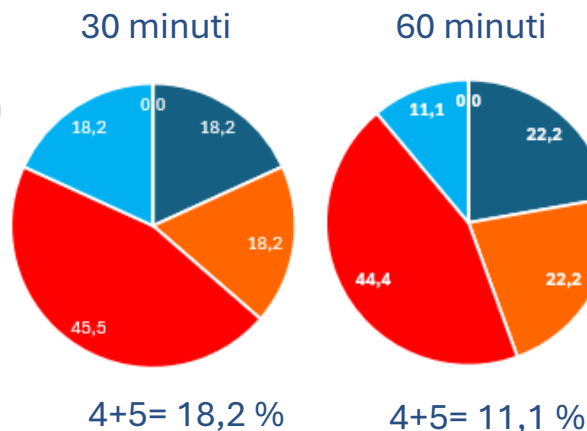
Senza giacca

- 1 Nessuna o molto leggera
- 2 Leggera
- 3 Moderata
- 4 Intensa
- 5 Molto intensa



Con giacca

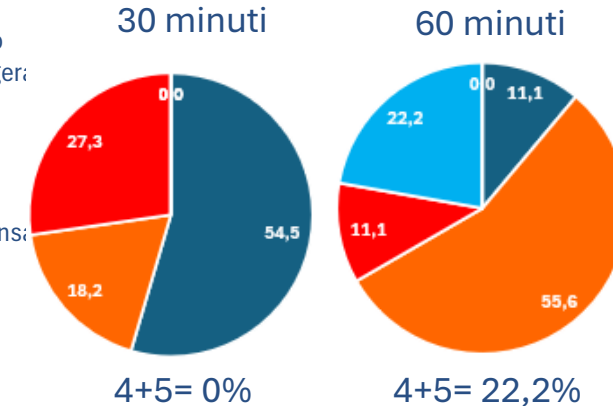
- 1 Nessuna o molto leggera
- 2 Leggera
- 3 Moderata
- 4 Intensa
- 5 Molto intensa



### Stanchezza

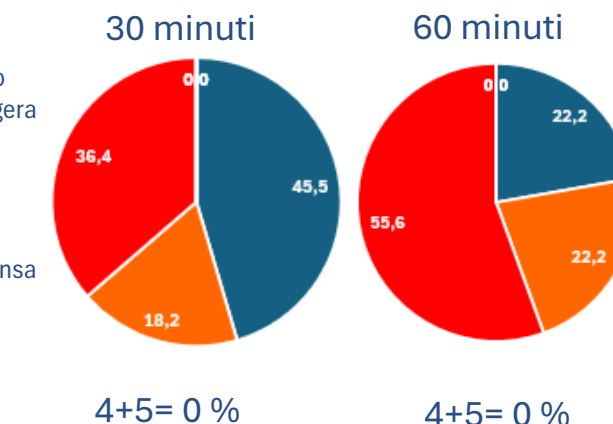
Senza giacca

- 1 Nessuna o molto legger.
- 2 Leggera
- 3 Moderata
- 4 Intensa
- 5 Molto intensa



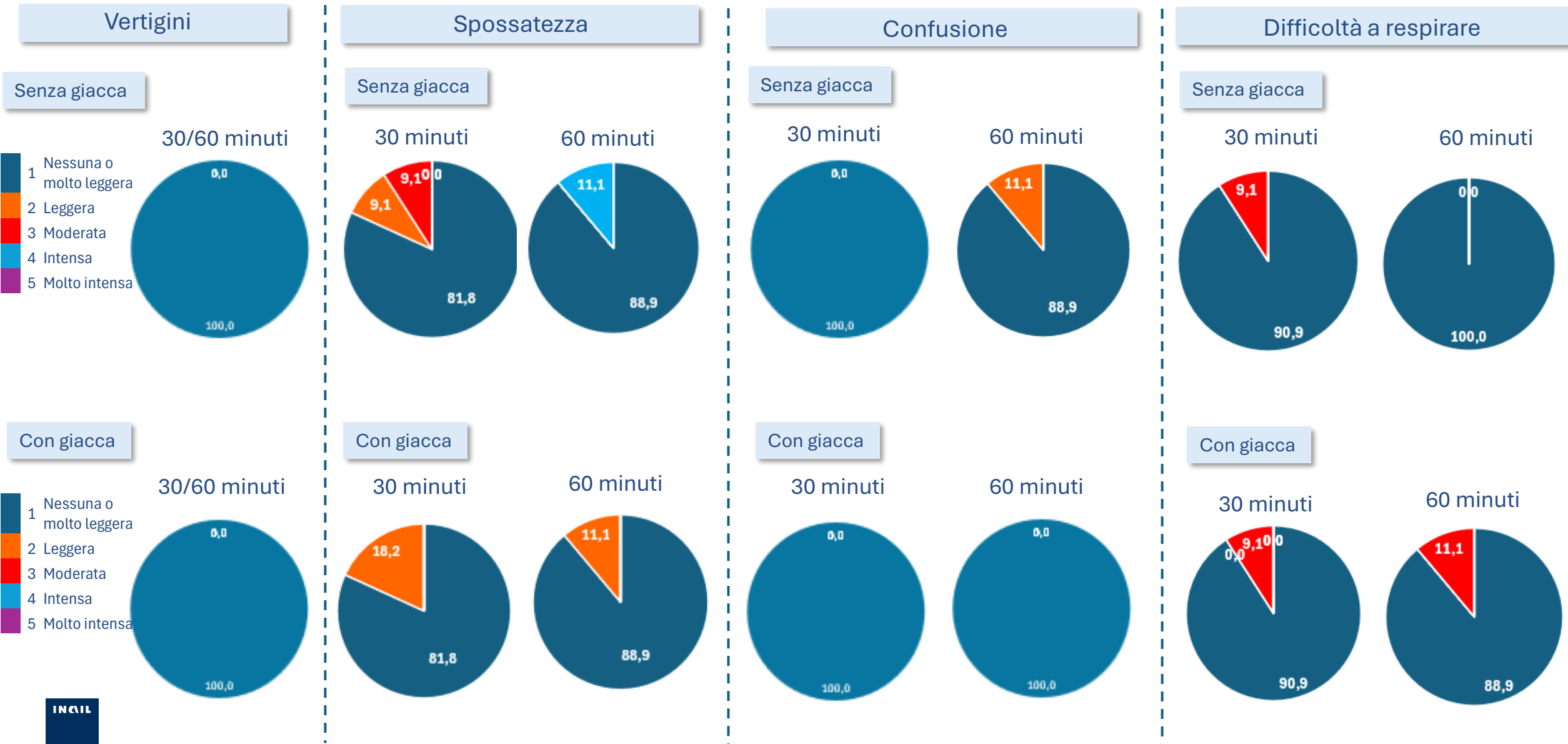
Con giacca

- 1 Nessuna o molto leggera
- 2 Leggera
- 3 Moderata
- 4 Intensa
- 5 Molto intensa



# Il questionario: sintomi percepiti

## Quali segni/sintomi hai percepito mediamente negli ultimi 30 minuti?



# Il questionario: le sensazioni termiche

■ molto caldo ■ caldo ■ tiepido ■ leggermente tiepido ■ neutro ■ leggermente fresco ■ fresco ■ freddo ■ molto freddo

Complessivamente  
come si è sentito?

Come ti sei sentito  
nel petto?

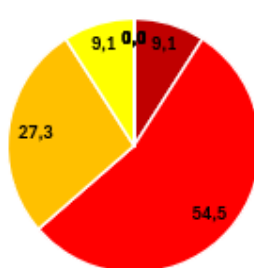
Come ti sei sentito  
nell'addome?

Come ti sei sentito  
alle spalle?

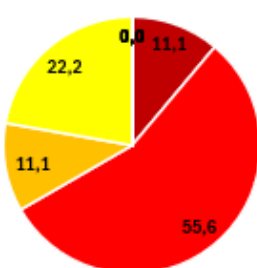
Come ti sei sentito  
nella schiena?

Senza giacca

30 minuti

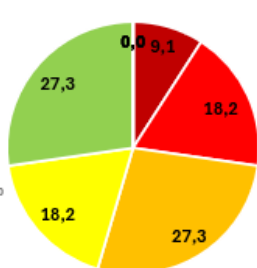


60 minuti

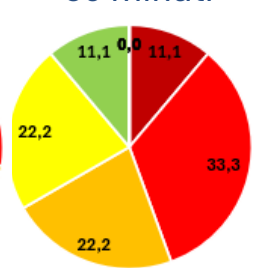


Senza giacca

30 minuti

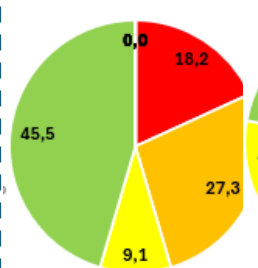


60 minuti

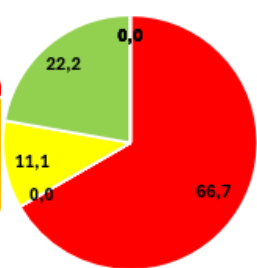


Senza giacca

30 minuti

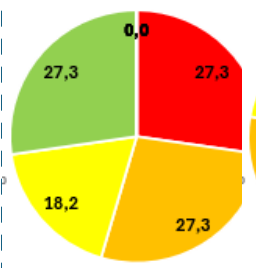


60 minuti

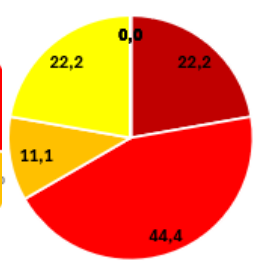


Senza giacca

30 minuti

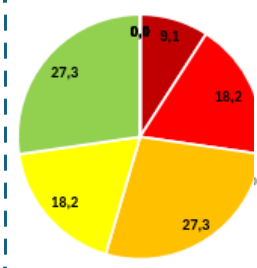


60 minuti

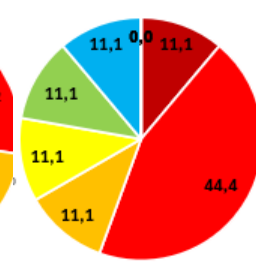


Senza giacca

30 minuti

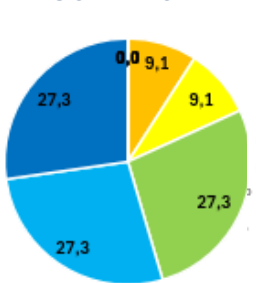


60 minuti

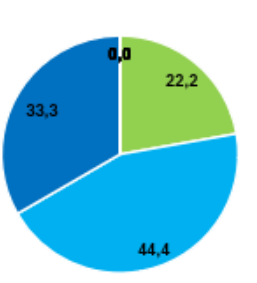


Con giacca

30 minuti

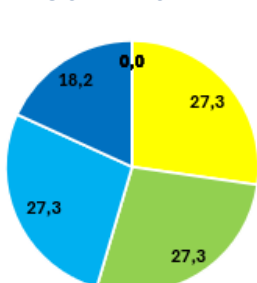


60 minuti

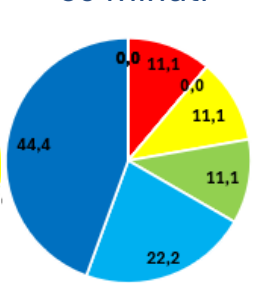


Con giacca

30 minuti

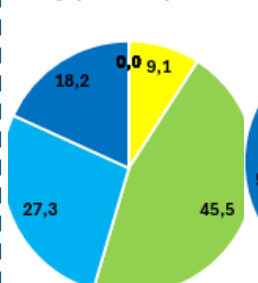


60 minuti

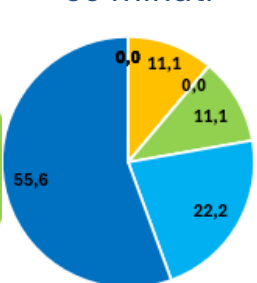


Con giacca

30 minuti

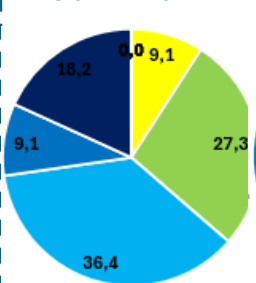


60 minuti

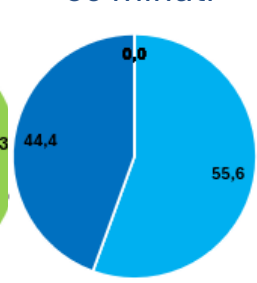


Con giacca

30 minuti

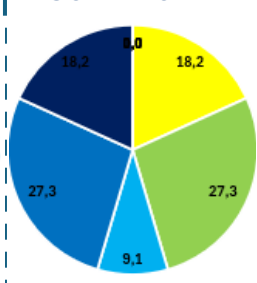


60 minuti

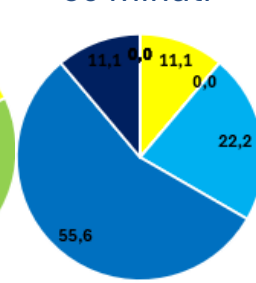


Con giacca

30 minuti



60 minuti



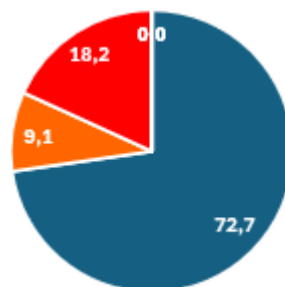
# Questionario: usabilità e accettabilità

Domanda 1

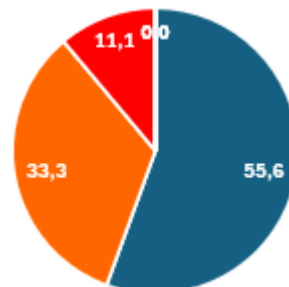
La giacca ventilata ostacola i miei movimenti

30 minuti

60 minuti



1+2= 81,9%



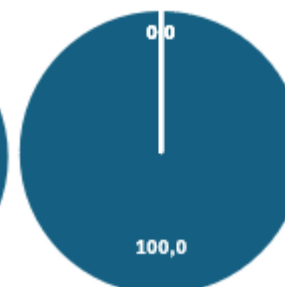
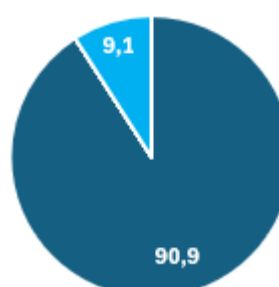
4+5= 88,9%

Domanda 2

La giacca ventilata è pesante

30 minuti

60 minuti

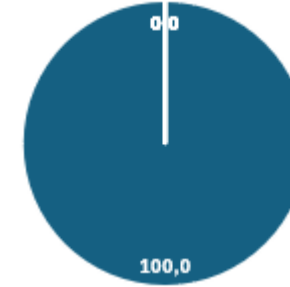
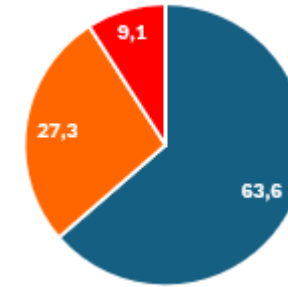


Domanda 3

La giacca ventilata mi rallenta durante il lavoro

30 minuti

60 minuti

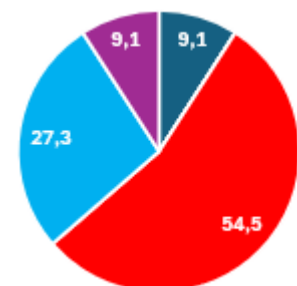


Domanda 4

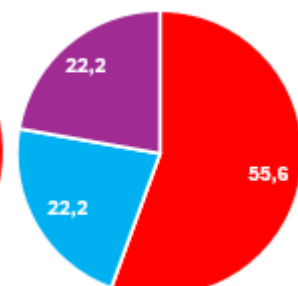
La giacca ventilata riduce la mia sensazione di caldo

30 minuti

60 minuti



4+5= 36,4%



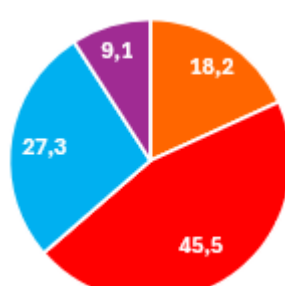
4+5= 44,4%

Domanda 5

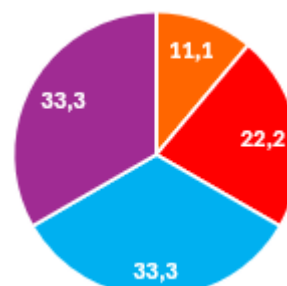
Userei la giacca ventilata se potessi averla a disposizione durante i lavori al caldo

30 minuti

60 minuti



4+5= 36,4%



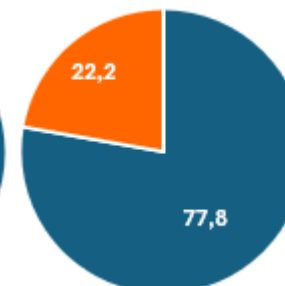
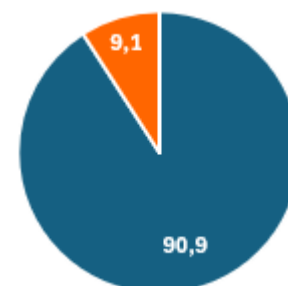
4+5= 66,6%

Domanda 6

L'intensità della ventilazione della giacca ventilata è eccessiva per me

30 minuti

60 minuti

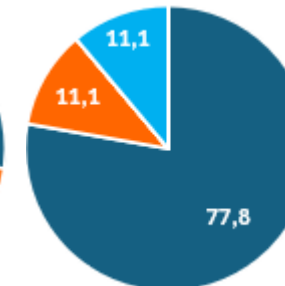
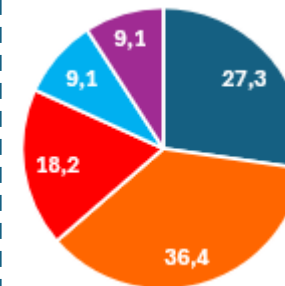


Domanda 7

L'intensità della ventilazione della giacca ventilata è insufficiente per me

30 minuti

60 minuti





Grazie per l'attenzione