PAPER • OPEN ACCESS

Thermal comfort of *dual-chamber* ski gloves

To cite this article: F Dotti *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **254** 182002

View the article online for updates and enhancements.

Related content

- Energy Conversion for Thermal Comfort and Air Quality Within Car Cabin
  Daniel Kristanto and Thananchai Leephakpreeda
- Influence of textile properties on thermal comfort
  A Marolleau, F Salaun, D Dupont et al.
- The Analysis of Thermal Comfort in Kitchen
  Fety Ilma Rahmillah, Agustina Hotma Uli Tumanggor and Amarria Dila Sari

IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

This content was downloaded from IP address 5.62.152.157 on 29/09/2018 at 12:31

IOP Conf. Series: Materials Science and Engineering **254** (2017) 182002 doi:10.1088/1757-899X/254/18/182002

Thermal comfort of *dual-chamber* ski gloves

F Dotti[1], M Colonna[2] and A Ferri[1]

[1]Politecnico di Torino, Department of Applied Science and Technology, Corso Duca degli Abruzzi 24, 10129 Torino (Italy)
[2]Università di Bologna, Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Via Terracini 28, 40131, Bologna, Italy

E-mail: ada.ferri@polito.it

Abstract. In this work, the special design of a pair of ski gloves has been assessed in terms of thermal comfort. The glove 2in1 Gore-Tex has a dual-chamber construction, with two possible wearing configurations: one called "grip" to maximize finger flexibility and one called "warm" to maximize thermal insulation in extremely cold conditions. The dual-chamber gloves has been compared with two regular ski gloves produced by the same company. An intermittent test on a treadmill was carried out in a climatic chamber: it was made of four intense activity phases, during which the volunteer ran at 9 km/h on a 5% slope for 4 minutes, spaced out by 5-min resting phases. Finger temperature measurements were compared with the thermal sensations expressed by two volunteers during the test.

Introduction

Skin temperature is a nearly linear function of the perfusion of the hand, as it was demonstrated by Laser Doppler measurements. Due to vasoconstriction, blood flow decreases of about 30% at 15°C compared to 31°C [1]. Having small muscles, hands have a very low intrinsic heat production, which has been estimated merely as 0.25 W [2]. Therefore it is important that hands have continuous heat supply from the body core. A mean skin temperature of 15°C is said to be the lowest acceptable skin temperature for sufficient dexterity and thermal self-perceived comfort [3]; however, much lower temperatures of skin hands have been registered in cold environmental conditions.

Although fabric thickness influences thermal and evaporative resistance of fabric assembly, the influence of air gaps under the clothing is more significant. Taking into account fit and thermal comfort, the local ease allowance for cold protective clothing is suggested to be within 10mm. Fit is extremely important also for gloves and it is plausible that both tight fit and loose fit are not ideal: in the first case, conductive heat loss plays a major role while in the second case convective heat loss due to air circulation in the glove can be relevant. Concerning gloves, specific norms such as EN 420:2010+A1 are available for protective equipment only [4]. The size of the glove is given by a number between 6 and 11. The code is a conventional designation of hand size corresponding to the hand circumference expressed in inches. In Table 1, the size of the hand reported in the standard is shown.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

Tests in climatic chamber can be used to validate thermal insulation of garments in extreme conditions [5].

Table 1. Hand and glove size, according to EN 420:2010

Hand/ glove size	Hand circumference (mm)	Hand length (mm)
6	152	160
7	178	171
8	203	182
9	229	192
10	254	204
11	279	215

In this work, the special design of a pair of ski gloves has been assessed in terms of thermal comfort. The glove 2-in-1 Gore-Tex has a dual-chamber construction, with two possible wearing configurations: (1) one called "grip" to maximize hand dexterity and (2) one called "warm" to maximize thermal insulation in extremely cold conditions. Both subjective and objective parameters related to thermal comfort have been monitored during the test. The final aim of the work was to compare the thermal performance of the dual chamber glove with respect to two single chamber glove models.

Experimental

The 2in1 Gore-Tex glove shown in Figure 1 was compared with two regular ski-gloves produced by the same company and classified as Thermoplus 3000 (that is a product certified for temperatures up to -15°C) and Thermoplus 4000 (that is a product certified for temperatures up to -20°C).

Figure 1. Dual-chamber ski gloves

The test in the climatic chamber was carried out by two healthy male volunteers of age 30 and 33, both fitting size 8.5 gloves. Each volunteer carried out the wear trial three times (once for each type of gloves) at the same hour to avoid the effect of circadian rhythms. Apart from the gloves, the outfit made of ski-pant & jacket, warm fleece and underwear was the same in each wear trial.
The climatic chamber air temperature and humidity were respectively -10.46±0.33°C and 66.44±3.17%.
The physical activity test was made of two intense activity phases, during which the volunteer ran at 9 km/h on a 5% slope for 4 minutes, spaced out by 5-min resting phases. The test was preceded by 15-min acclimatization walk at 3.5 km/h and followed by 10-min rest in the climatic chamber.

During the test, thumb, middle and little finger temperatures were measured by means of thermocouples (see Figure 2).

Figure 2. Location of the thermocouples for the measurements of finger tips temperature.

Thermal sensations experienced by the volunteers were collected through a questionnaire. During each test, the volunteer was asked to express his subjective assessment of finger temperature any two minutes. The bipolar scale used for subjective assessment of thermal environments as reported in UNI EN ISO 28802:2012 norm [6] was adopted, with the following thermal sensations, which were assigned a numerical value.

Table 2 Numerical values associated with thermal sensations

Subjective thermal sensation	Associated numerical value
Hot	+3
Warm	+2
Slightly warm	+1
Neutral	0
Slightly cool	-1
Cool	-2
Cold	-3

Results and discussion

The average temperature of the left and right hand fingers over the two volunteers is shown in Figure 3. It can be observed that finger temperature dropped during the initial acclimatization phase with any gloves; however, the fall was steeper for 2-in-1-Grip than 2-in-1-Warm between 500 to 900 seconds, confirming that 2-in-1-Warm configuration is more insulating. At the end of the acclimatization phase, finger temperature was close to the acceptability limit of 15°C with 2-in-1-Grip and Thermoplus 3000 while was inside the comfort limit for Thermoplus 4000 and 2-in-1-Warm.

Due to metabolic heat production during the physical test, fingers temperature was restored to initial value in case of 2-in-1-Warm and Thermoplus 4000 while it remained well below initial temperature in case of Thermoplus 3000 and was only partially restored with 2-in-1-Grip.

The weave trend of finger temperature during the activity phases (between 900 and 2100 sec) is the result of vasodilatation and vasoconstriction associated with intense activity and resting phase respectively. As expected, vasodilatation contributed tremendously to restoring comfortable finger temperature. The steepest increase in finger temperature was observed just after the end of the second high intense activity phase and it was prolonged in the recovery phase. This peak was the result of two combined effects: vasodilatation, which was maximum just before the end of the test, and convective heat loss. Convective heat loss was evidently greater during the activity phase as the volunteer was moving his hands while running. As the physical activity suddenly stopped, the hands were hanging

down along the body with little movement and this change of posture reduced the effect of heat loss by air convection.
However, some minutes after the end of the activity phase, the finger temperature reached a peak and started decreasing again, as heat flow was not longer supported by high metabolic rate.

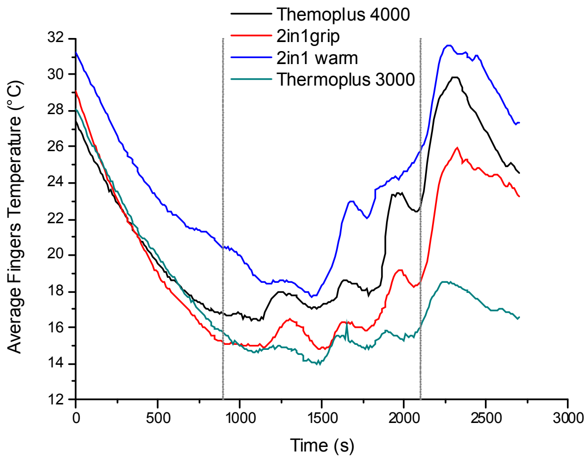

Figure 3 Average finger temperature of the dual-chamber gloves in comparison with the two reference gloves Themoplus 3000 and Thermopus 4000.

The descending and ascending sections of the temperature curve were regressed with linear equations, whose slopes give an idea of the glove thermal insulation. In Table 3, the regression lines are shown.

Table 3 Slopes of the linear regressions of temperature curves

	Descending linear equation slope	Ascending linear equation slope
Thermoplus 4000	-0.012	+0.0051
2-in-1 Grip	-0.015	+0.0029
2-in-1 Warm	-0.012	+0.0059
Thermoplus 3000	-0.014	+0.0007

By comparing the slope values, it can be observed that the temperature drop was the steepest for 2-in-1 Grip, followed by Thermoplus 3000, while Thermoplus 4000 and 2-in-1 Warm had the same slope, meaning that they provided approximately the same thermal insulation.
For the ascending section, the steepest temperature increase was observed for 2-in-1 Warm, followed by Thermoplus 4000, 2-in-1 Grip and Themoplus 3000.
Regarding the subjective assessments, the results of the questionnaire are shown in Figure 4. The four phases shown in the figure are the following:
Phase 1: end of the acclimatization phase
Phase 2: end of the first intense activity phase
Phase 3: end of the second intense activity phase
Phase 4: end of the recovery phase

IOP Conf. Series: Materials Science and Engineering **254** (2017) 182002 doi:10.1088/1757-899X/254/18/182002

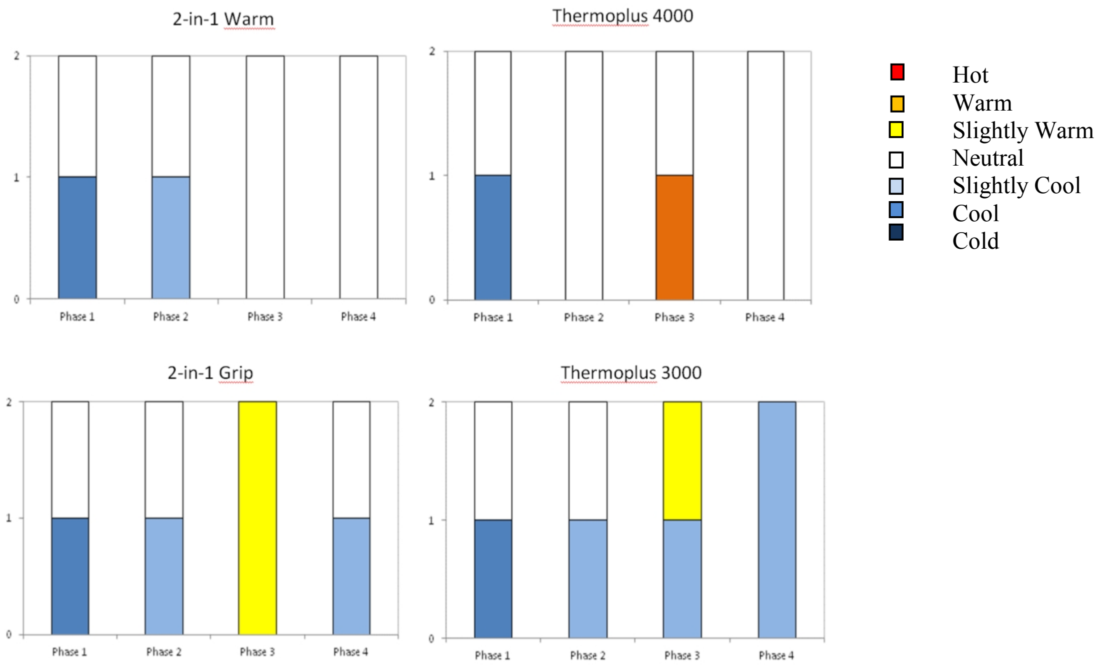

Figure 4 Thermal subjective assessments.

Wearing Themoplus 3000, *Cold* or *Cool* assessments were dominant throughout the duration of the test while *Cold* assessment was limited to the acclimatization phase with Thermoplus 4000 and was turned into *Warm* or *Neutral* assessments during and after the activity phase.

2-in-1-Warm and 2-in-1-Grip were in the middle: negative *Cold* assessments were restricted to the acclimatization and first activity phase.

Thermal subjective sensations (expressed in numerical values) can be plotted versus finger temperature as shown in Figure 5 for Thermoplus 4000 as example.

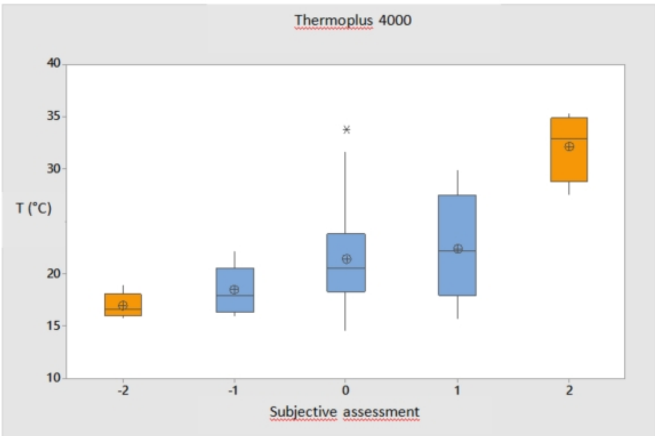

Figure 5 Subjective thermal sensation vs. finger temperature.

It can be observed that comfortable sensations (in blue) were associated with finger skin temperature between 15°C and 30°C. Above 30°C finger temperature was considered uncomfortably *Warm* and between 15°C and 20°C uncomfortably *Cool* or comfortably *Slightly Cool*.

Acceptability assessments are shown in Figure 6. All gloves showed a certain discomfort in the acclimatization and first activity phase while acceptability was achieved during the second activity phase and was maintained until the end of the test, with the exception of Thermoplus 3000 which was considered barely acceptable due to cold at the end of the test by one volunteer.

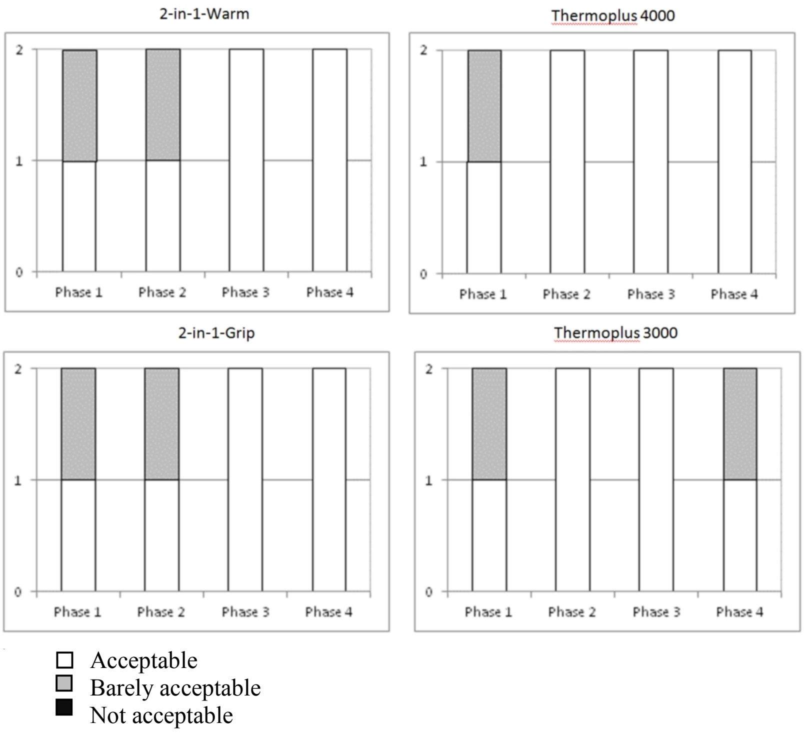

Figure 6 Acceptability of subjective assessments.

Conclusions

Thermal comfort of *dual-chamber* ski gloves has been assessed through wear trials in controlled conditions in a climatic chamber. In any configuration, finger temperatures did not drop below the comfortable limit of 15°C, suggesting that both configurations guarantee comfortable conditions during physical activity comparable with downhill skiing in terms of metabolic rate. 2-in-1-Grip was found to be more insulating than a reference glove certified for temperature as low as -15°C and 2-in-1-Warm was slightly less insulating than a reference glove certified for -20°C.

Acknowledgments
The authors acknowledge the company LevelGloves for providing financial support to this work.

References

[1] Glitz KJ, Seibel U, Kurz B, Uedelhoven W, Leyk D 2005 *Thermophysiological and self-perceived sensations during cold exposure of the hands: data for a biophysical device*. In: Holmér I, KuklaneK, Gao C (eds) Environmental Ergonomics XI, Ystad, pp 564–566
[2] Raman ER, Vanhuyse VJ 1975 *J Physiol* **249** 197–210
[3] Hamlet MP 1988 Human Cold Injuries. In: Pandolf K, Sawka M,Gonzalez R (eds) *Human performance: Physiology and environmental medicine at terrestrial extremes*. Benchmark Press, Indianapolis
[4] EN420: 2003+A1 Protective gloves - General requirements and test method
[5] Dotti F, Ferri A, Moncalero M, Colonna M 2016 *Appl. Erg*onomics **56** 144
[6] UNI EN ISO 28802:2012 *Ergonomic of the physical environment*