WOOLMARK

WOOL'S PERFORMANCE AND COMFORT FOR STOP-GO SPORTS

Merino wool's superior performance in stop-and-go sports is no longer anecdotal. A four-year study by North Carolina State University confirms that wool garments outperform other fibres by maximising thermal comfort and minimising after-chill during rest periods. By naturally regulating temperature, managing moisture, and resisting odours, Merino wool base-layers could also help athletes conserve energy for the activity itself.

The study also introduces a new test method that could enable designers and brands to optimise fabric choice for specific sports or activities, demonstrating that wool delivers natural, high-performance functionality for demanding athletic conditions.

HOW WOOL WORKS IN STOP-GO SPORTS

Active outdoor sports such as hiking, cycling, and rock climbing are known as stop-go sports because they involve surges of physical effort followed by rest periods. During activity, athletes sweat; during rest, moisture evaporates from clothing. Wool's natural fibre structure buffers these shifts, keeping skin temperature stable.

New research shows wool delivers 96% greater moisture buffering than polyester, 45% greater than cotton, and 25% greater than viscose.

The secret of wool's performance lies in the fibre's complex structure. A moisture-wicking core is surrounded by a liquid-repellent outer-layer, balancing comfort and breathability, while the fibre's crimped structure captures tiny insulating air pockets next to the skin, retaining or transmitting heat as needed. Additionally, odour molecules are naturally trapped within the fibre, keeping athletes fresher for longer.

STOP-GO SPORTS AND THERMAL COMFORT

An inherent feature of 'stop-go' sports is the ongoing sequence of activity and rest. Stop-go sport athletes are sensitive to the thermal changes experienced as their garments alternate between the heat generation of the sweating phase and the endothermic cooling of the drying phase.

The ability of wool garments to maintain more stable thermal comfort by buffering the microclimate between the fabric and the skin is well documented.

"wool maintains its insulating properties when damp"

"I get neither cold, nor more importantly, hot and sweaty"

"It still keeps you warm even when wet"

AFTER-CHILL AND PERFORMANCE

Stop-go sport athletes are sensitive to thermal changes experienced as their garments respond to the heat generation of the sweating phase and the evaporative cooling of the resting phase. This discomfort, often called after-chill, can distract athletes and prevent peak performance.

Historically, competing cyclists insulated their jerseys with newspapers before a descent to prevent after-chill and conserve energy.

With the human body continuously working to maintain a skin temperature of 35°C, a proposed new test method shows less work is needed in wool, allowing athletes to stay comfortable and focus all available energy on the sport itself.

Historically, cyclists in the Tour de France insulated their jersey with newspapers before a descent to prevent wind chill and save calories.

WHAT THE CURRENT SCIENCE SAYS

Thermal comfort concerns the maintenance of body temperature at an optimum level (35°C +/- 0.5°C) not only during stable conditions, but also during changes in either the immediate environment (such as moving from hot to cold) or the body's metabolic rate (such as conducting or ceasing exercise). Humans rely on clothing to help regulate their body temperatures.

WHAT THE LATEST SCIENCE SAYS

A four-year study at North Carolina State University explored the performance of different fabric types in stop-go sports, leading to the development of a new test method to better inform garment design. The researchers compared 100% wool, 100% cotton, 100% viscose, and 100% polyester garments of similar fabric weight and thickness using sweating manikins programmed to replicate the heat and moisture output of athletes in motion. The manikins were cycled through controlled humidity chambers that mimicked the rapid environmental shifts experienced in stop-go sports.

Human participants then confirmed the trials, providing subjective comfort scores alongside physiological data. This combined approach provided a more holistic view of fabric behaviour throughout all phases of exercise. Wool rose to the top on both perceived comfort and thermal sensation - the very factors that define user experience.

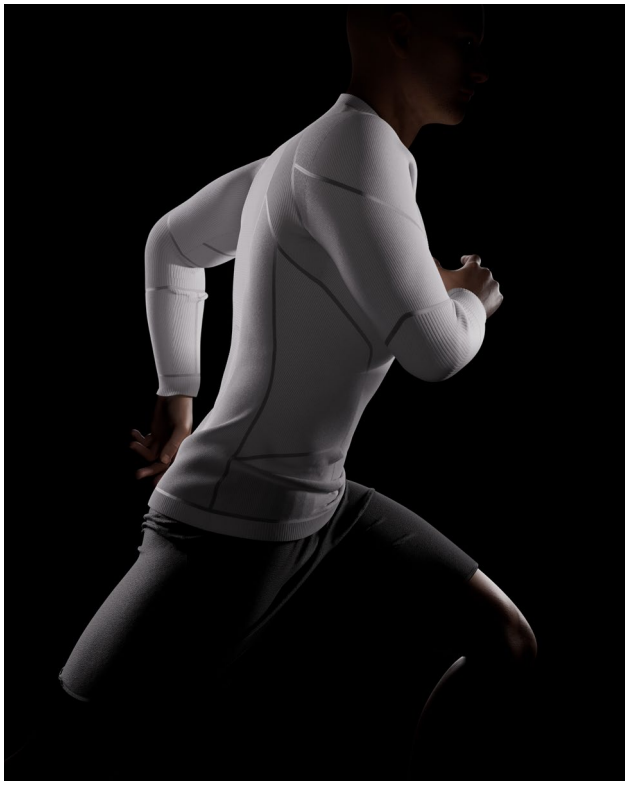
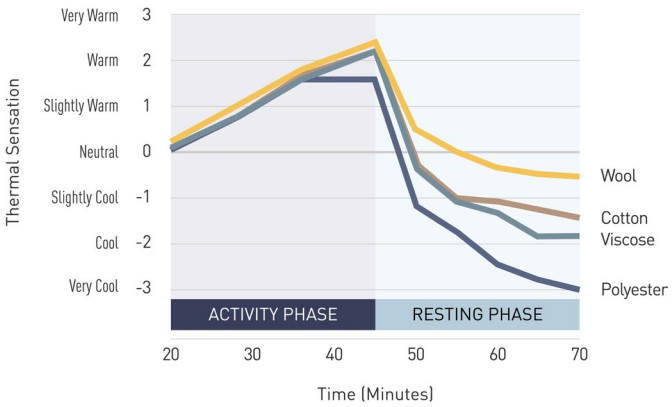


Figure 1 demonstrates that during the activity phases of exercise no significant differences in thermal sensation or perceived comfort are experienced, but during the resting phases athletes can be exposed to unwanted cooling depending on the fabric type.

Thermal Sensation



Perceived Comfort

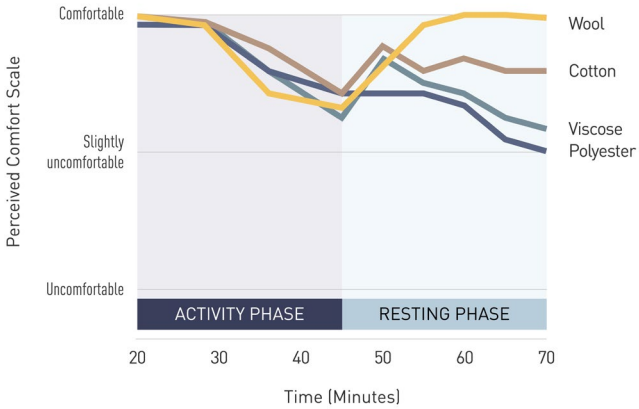


Figure 1: Human Studies - Experience during exercise and rest in a cool (15°C) environment.

THE ASTM F3628 TEST METHOD

Utilising a sweating guarded hotplate in a temperature and humidity-controlled environment, the proposed test method mimics stop–go activity patterns by turning sweating on and off for controlled periods. The standard semi-permeable membrane between the fabric and the hotplate is omitted, enabling a fixed amount of liquid water (sweat) to permeate the fabric. This equipment measures the cooling power of a fabric required to maintain the hotplate temperature of 35°C as sweat is absorbed and then evaporates.

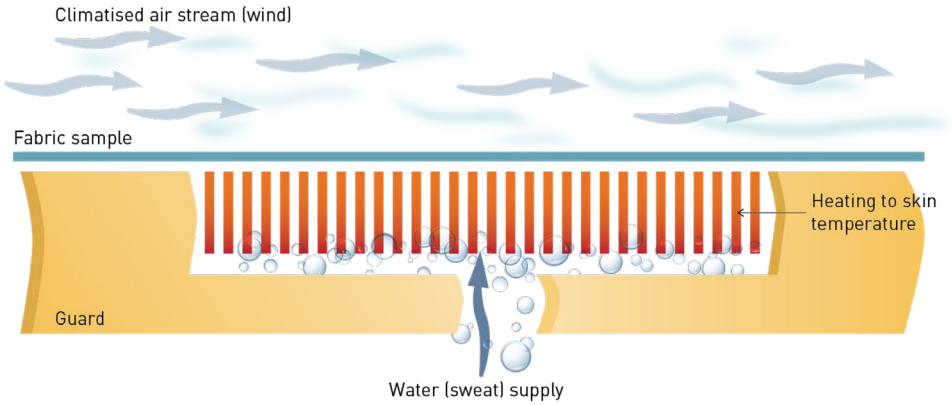


Figure 2: Modified sweating guarded hotplate - with no semi-permeable membrane.

This test method differentiates fibre performance by tracking shifts in cooling power across the activity (sweating) and resting (non-sweating) cycles.

Figure 3 shows wool to progressively increase cooling power as the athlete needs it, with minimal volatility in cooling power between activity and resting phases.

Marked contrasts between the maximum and minimum cooling power across the phases are an indication of a fabric's potential for after-chill with the results indicating high-potential for both polyester and cotton.

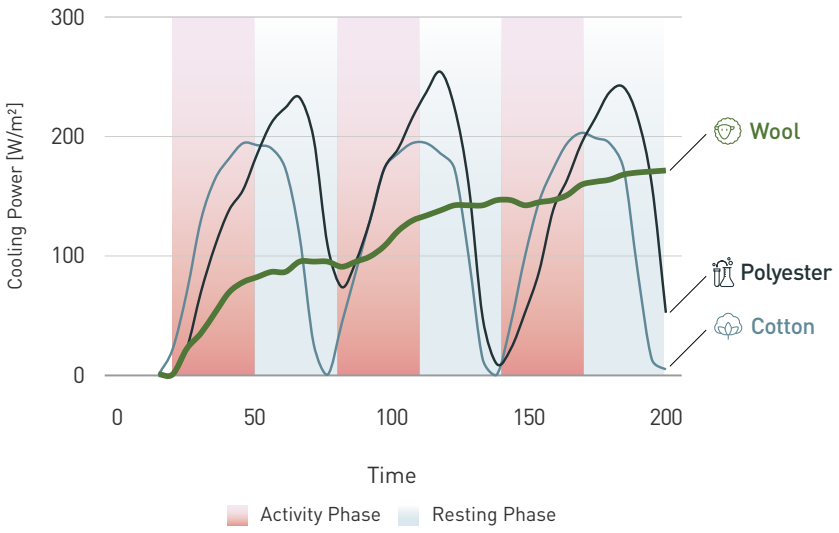


Figure 3: Cooling power curves for three fibre types over 3 simulated stop-go cycles of exercise.

To recreate dynamic stop-go sports in a lab, a new test method has been developed utilising the existing Sweating Guarded Hot Plate*.

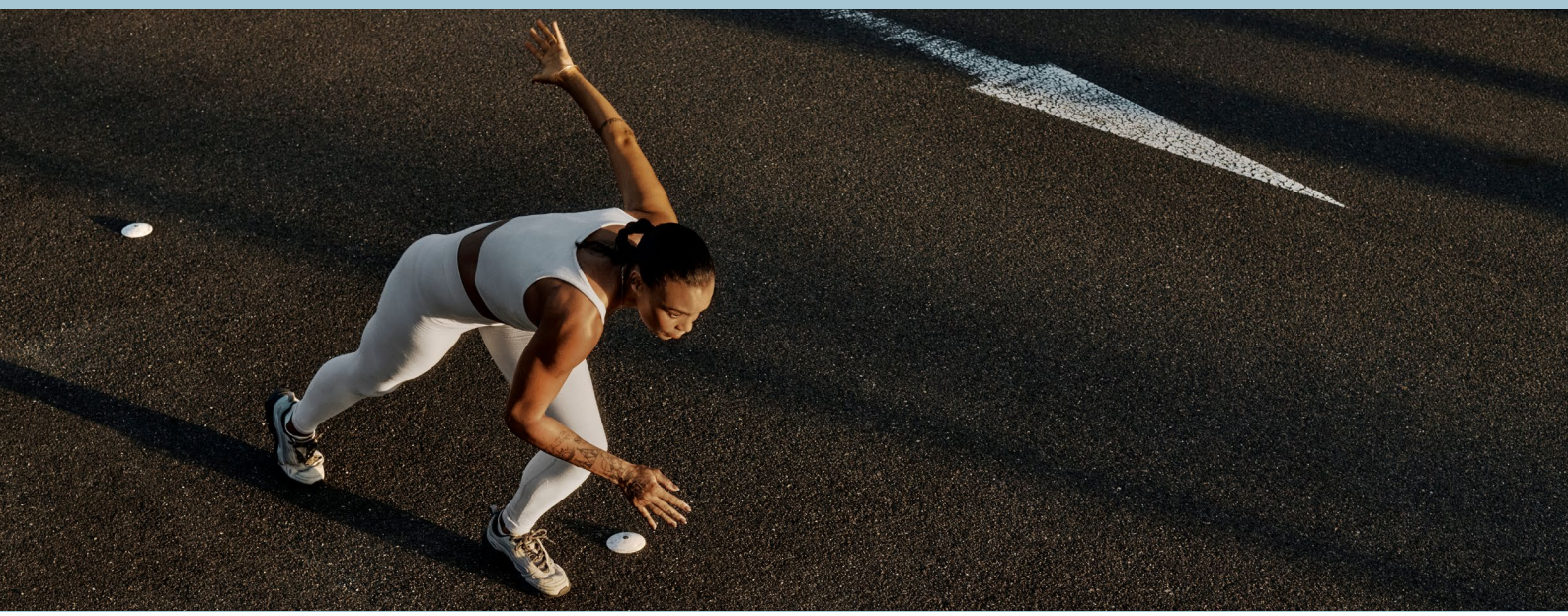
These adaptations included:

- Semi-permeable membrane not present enabling liquid water (sweat) transfer
- Increasing the wind speed
- Testing across three cycles of sweating/non-sweating

*SGHP (ISO 11092) simulates skin conditions to measure the thermal and vapour resistance of a fabric, and how these may influence its comfort properties.

Noteworthy points on Figure 3 include:

- Polyester peak cooling is delayed by almost 15 minutes into resting phases due to poor moisture absorption.
- Wool absorbs up to 35% of its weight in moisture without feeling wet; cotton absorbs ~20% but feels damp.
- Cooling power volatility is measured by linearity of the cooling curve: wool 74%, cotton and polyester <1%.
- Measuring the area under the curve provides an estimate of the energy required to maintain thermal comfort over the three cycles of activity and rest. The wool fabric is the most energy efficient at 12.6kJ/m2 whereas the polyester fabric uses an additional 20% energy to maintain thermal equilibrium.



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- New research shows wool delivers 96% greater moisture buffering than polyester, 45% greater than cotton, and 25% greater than viscose.

Abedin, Faisal, and Emiel DenHartog. "A new approach to demonstrate the exothermic behavior of textiles by using a thermal manikin: Correction methods of manikin model." Polymer Testing 128 (2023): 108195.

- The ability of wool garments to maintain more stable thermal comfort by buffering the microclimate between the fabric and the skin is well documented .
- For an athlete wearing base-layer clothing, the effect of decreased metabolic rate on comfort can be dramatic. The body must create heat using stored energy reserves to maintain core body temperature.

Li, Y The Science of Clothing Comfort, Text Prog 31 2001 p 55

- Humans rely on clothing to help regulate their body temperatures and wool, more than all other common apparel fibres, helps maintain a more stable microclimate between the garment and the body.

Li, Y. Holcombe B. V. and Apcar F., Moisture buffering behaviour of hygroscopic fabric during wear, Textile research Journal, 1992, 619-627.

- The two properties of thermal insulation and moisture vapour management are coupled and can impart a series of benefits to users of wool products through acting independently or in combination

J. C. Barnes and B.V. Holcombe, Moisture Sorption and transport in clothing during wear, Textile Research Journal, 1996, 77-786.

- As a result of North Carolina State University's four-year study, the reasons for wool's benefits to wearers are now better understood.

Abedin, F.; DenHartog, E. The Exothermic Effects of Textile Fibers during Changes in Environmental Humidity: A Comparison between ISO:16533 and Dynamic Hot Plate Test Method. Fibers 2023, 11, 47. https://doi.org/10.3390/fib11050047

Abedin, Faisal, and Emiel DenHartog. "A new approach to demonstrate the exothermic behavior of textiles by using a thermal manikin: Correction methods of manikin model." Polymer Testing 128 (2023): 108195.

- No significant differences between fibres in perceived comfort or thermal sensation during the activity phase;
- only wool maintained ongoing comfort throughout the resting phase, with after-chill experienced for all other fibre types; and
- thermal performance differences are long-lived, with fibres still diverging after 25 minutes.

Abedin, Faisal, and Emiel DenHartog. "Clothing impact on post-exercise comfort: skin-clothing physiology in transient environment." Ergonomics (2023): 1-17.

- Fabric test methods such as ISO 11092 (Methods for the measurement of the thermal resistance and water-vapour resistance, under steady-state conditions) are consequently unable to effectively distinguish the thermal comfort performance of garments made from different fibre types.

J. Huang, Sweating guarded hot plate test method, Polymer Testing, Volume 25, Issue 5, 2006, p709-716

Garcia Torres E, Abedin F and DenHartog E. "Latent heat loss through fabrics during an alternate simulated work–rest sequence." AATCC J Res 2024; 11(12):282–288.

Kedena Henriques-Thompson , Edgar Garcia Torres and Emiel DenHartog, "Dynamic behavior of textiles during multiple work–rest sequences." AATCC Journal of Research 2025, Vol. 12(5) 1–9

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