Report on manikin measurements for ASHRAE 1504-TRP: Extension of the Clothing Insulation Database for Standard 55 and ISO 7730 to provide data for Non-Western Clothing Ensembles, including data on the effect of posture and air movement on that insulation. Results of Cooperative Research between the American Society of Heating Refrigerating and Air Conditioning Engineers, Inc., and the Universities of Loughborough, Lund, Cornell and Hong Kong.

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Report on manikin measurements for ASHRAE 1504-TRP

Extension of the Clothing Insulation Database for Standard 55 and ISO 7730 to provide data for Non-Western Clothing Ensembles, including data on the effect of posture and air movement on that insulation.

Results of Cooperative Research between the American Society of Heating Refrigerating and Air Conditioning Engineers, Inc., and the Universities of Loughborough, Lund, Cornell and Hong Kong.

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List of Symbols

$Corr_{wind0.4}$ = correction factor to obtain value at air velocity 0.4 m.s^{-1} relative to value at 0.2 m.s^{-1}

$Corr_{wind1.0}$ = correction factor to obtain value at air velocity 1 m.s^{-1} relative to value at 0.2 m.s^{-1}

$Corr_{walking}$ = correction factor to obtain value while walking relative to the static value, both at 0.2 m.s^{-1}

$Corr_{sitting}$ = correction factor to obtain value while sitting relative to the static standing value, both at 0.2 m.s^{-1}

f_{cl} = clothing area factor: ratio between the surface area of the clothed body, including unclothed parts, and the surface of the nude body

I_a = Insulation of air layers surrounding manikin and clothing

I_{cl} = Intrinsic clothing insulation value (without surrounding boundary air layers)

I_m = moisture permeability index (Woodcock permeability index); ratio between the total dry clothing heat resistance (IT) and the total evaporative clothing heat resistance (Re,T) for a clothing ensemble, divided by the Lewis relation (16,5 K/kPa)

I_T = Total insulation value of clothing plus surrounding boundary air layers

$I_{T,\text{static}}$ = I_T at 0.2 m.s^{-1} air velocity, static. = $I_{T,0.2m/s}$

$I_{T,0.2m/s}$ = I_T at 0.2 m.s^{-1} air velocity, static

$I_{T,0.4m/s}$ = I_T at 0.4 m.s^{-1} air velocity, static

$I_{T,1.0m/s}$ = I_T at 1.0 m.s^{-1} air velocity, static

L = Lewis relation; ratio of the evaporative heat transfer coefficient to the convective heat transfer coefficient

n.d. = non dimensional number

$R_{e,a}$ = evaporative resistance of the boundary air layer; resistance to vapor transport for the whole body at the boundary (skin or clothing)

$R_{e,T}$ = evaporative resistance of a clothing ensemble; resistance to vapor transport of a uniform layer of insulation covering the entire body that has the same effect on evaporative heat loss as the actual clothing under the tested conditions.

Executive Summary

ASHRAE standard 55, ISO 7730 and chapter 9 in ASHRAE Handbook-Fundamentals titled 'thermal comfort' provide guidance for the assessment of thermal comfort in buildings. As inputs, the method uses climate parameters, the users' activity level and the clothing insulation of the garments worn by the occupants.

The standard provides guidance on the determination of these parameters and provides examples of values for activity level and clothing insulation. However, for the latter, the emphasis is on western style clothing, while in large parts of the world other clothing styles are worn, e.g. shalwar kameez in Pakistan, African clothing in Nigeria or Sarees in India. In order to use the methodology of ASHRAE 55 in non-western regions, insulation data for such clothing is required. In the present project, ASHRAE 1504-RP, such data was collected for a range of non-western clothing types.

Four different thermal manikins (male and female shapes) in three different laboratories (UK, Sweden and China), were used to determine the clothing insulation values of 52 clothing configurations. These fifty two configurations were also tested for the effects of air velocity on insulation and forty three were tested for the effects of posture (sitting) and walking. The observed reductions in insulation for both air velocity and walking are higher than those presented in the literature for western ensembles, emphasizing the need for these new data. This effect is most likely related to more open weave fabrics and loose fit designs. Similarly the relation of the clothing surface area factor to intrinsic clothing insulation was different from that published for western clothing. Prediction equations for the clothing surface area factor f_{cl}, based on the new data only had limited predictive power, which however was also the case for those obtained in the past for western clothing. This issue seems to be commonly overlooked, as the use of these prediction equations is widespread. It has to be concluded that reliable f_{cl} values can only be obtained when these are actually measured as in the present work. Having said this, the concept of the f_{cl} factor for the non-western clothing may not work in the first place, as the wide falling robes and gowns do not match the cylindrical clothing and air layer model on which the f_{cl} concept is based.

The results provide an extensive database of insulation values of non-western clothing styles in different wear configurations, in different air velocities, postures and movement. As such this is expected to be a valuable addition to ASHRAE 55 and ISO 7730 and ISO 9920.

In addition, data obtained on the insulation of individual body parts can be used by CFD modelers to incorporate realistic insulation data in their models.

Introduction

An often heard criticism of methodologies developed in the western world by those applying them in other areas of the world is that they do not consider the special local circumstances. Predictions of human thermal comfort sensations (in terms of the PMV/PPD; ASHRAE Standard 55, ISO 7730) require information on the value of the clothing insulation as worn by occupants. Comprehensive data on clothing insulation values are available in the literature and standards documents (ASHRAE 55; ISO 7730; ISO 9920, McCullough, 1984, 1985; Olesen et al., 1983; Seppanen et al. 1972). However, the vast majority of these data are for western-style clothing ensembles only, with comparatively little information available on non-western ensembles (Al-Ajmi et al., 2006; Al-Rashidi et al. 2012). Clothing insulation is a crucial parameter in the assessment of thermal comfort (Fanger, 1970, Havenith et al. 2002, Al-Rashidi et al. 2009a,b, 2010, ASHRAE 2009) and therefore important for the optimal design of ventilation and air conditioning systems to achieve thermal comfort for the building occupants (Ahmad & Ibrahim, 2003, Cheong et al. 2003, Kwok & Chun, 2003). Furthermore, given the growing energy needs of large nations such as India, China, Pakistan, with often different clothing behavior from the west, precise knowledge of the clothing insulation parameter is essential in optimizing the ventilation and AC systems for these countries. Over the last two decades, many studies have looked at changes in clothing insulation under the influence of body and air movement, as it became clear that statically-measured insulation values did not represent real life situations in many buildings (McCullough, 1993, Havenith et al. 1990[a,b], Holmér et al, 1999, Havenith and Nilsson, 2004, Qian & Fan, 2006; Qian & Fan 2009; Wu, Fan & Yu, 2011) and work environments. Different clothing materials (cotton, nylon, polyester, etc.), body postures (seated v standing or walking) and states of motion (and hence air velocities) of the human body all affect the insulation value of clothing ensembles, with changes up to 40% being documented. Data are thus required as to the effects of different clothing materials, designs, body postures, as well as the effects of air movement (Havenith et al., 2002), on the values for insulation of body segments, and the body as a whole. For non-western clothing, it is expected that relationships observed for western clothing may not apply, due to the often very different clothing design. In Middle Eastern clothing, for example, the looser fit and long gowns promote movement of air that in turn affects the thermal comfort sensation of the wearer (Havenith, 2002). An example of this are the Bedouin robes (Shkolnik, 1980). Also for example the Indian 'Saree', made of silk or cotton, differs markedly from Western ensembles in terms of both vapor resistance and style. It is thus essential to investigate these and other non-Western ensembles, particularly those that are likely to result in significantly different thermal and vapor resistances compared with Western ensembles.

In order to fill this gap in knowledge, ASHRAE commissioned a research project "Extension of the Clothing Insulation Database for Standard 55 and ISO 7730 to provide data for Non-Western Clothing Ensembles, including data on the effect of posture and air movement on that insulation" under code 1504-TRP. The work was commissioned to a consortium of three research laboratories: Loughborough University, UK, Environmental Ergonomics Research Centre; Lund University, Sweden, Dept. of Design Sciences, EAT; and Hong Kong Polytechnic University, Institute of Textiles and Clothing.

The information gathered through this research will constitute an important new addition to the data in Standards documents. This additional information will enable users of Standard 55, ASHRAE Fundamentals and ISO documents (7730, 9920) to make more accurate comfort predictions under realistic conditions for people clothed in non-western attire as applicable for buildings, aircraft, rail and road vehicles. These more accurate data should allow improved energy-efficient design.

Objective

In indoor climate assessment and building ventilation and air-conditioning design, heavy use is made worldwide of the two almost identical standards: ASHRAE Standard 55 and ISO 7730. These standards require clothing insulation data of the building occupants as provided e.g. in ISO 9920. For non-western areas, clothing data for locally worn clothing ensembles are often not available (e.g. in the Middle East region), making the application of the standards difficult. This may then lead to ventilation and air conditioning systems that are not optimally designed, with possible energy wastage.

The objective of this research project was to extend the current databases of clothing ensemble insulation values used in the comfort standards ASHRAE-55 and ISO-7730. As mentioned, the present databases (ISO 9920; ASHRAE Fundamentals, 2009) contain very little non-western clothing ensembles; hence the project focused directly on non-western clothing from major population regions. Relevant culturally-specific clothing were selected and acquired for testing from Africa, China, South Asia and the Middle East, regions of the globe with major populations and rapidly-growing economies.

Apart from the clothing insulation while static, the effect of air movement and posture were also studied. Further, evaporative heat resistances were determined in the static condition.

Clothing was selected based on a review performed at the start of the project (Appendix C). An important finding of the initial review was that, for China, which originally was one of the main focusses of the project, clothing worn has changed almost fully to western style. Therefore only a small number of Chinese garments is used in the project and the clothing selection was widened beyond the original proposal for India, Pakistan, West Africa and Indonesia.

The contract with ASHRAE was based on the following minimum test numbers:

- Static Insulation (reference air velocity): 18 ensembles in 2 configurations = 36 ensemble tests;
- Evaporative Resistance measurement: 18 ensembles plus selection of configurations = 27 tests;
- Posture and walking: 18+ ensemble configurations;
- Air velocity effect: 18+ ensemble configurations at 3 air velocities.

Methods

A total selection of 52 ensemble configurations based on 27 basic ensembles from 7 countries was made. All 52 ensembles were tested statically and for the effect for air movement, while evaporative resistance and body posture were tested on 41 and 39 ensemble configurations, respectively. Each of the ensembles is described in detail in appendix A and B. The testing plan is shown in the Table 1 below:

Table 1; Testing schedule for the three laboratories. For explanation of the garment combinations see Appendix A.

Garment identifier	Country	Gender	Lund Dry Resistance, Posture and Walking	Hong Kong Dry and vapor Resistance	Loughborough Dry Resistance & air velocity
A1	Pakistan	Female	1	1	1
A2	Pakistan	Female	1	1	1
B1	India	Female	1	1	1
B2	India	Female			1
C	Pakistan	Male	1	1	1
D1	Pakistan	Female	1	1	1
D2	Pakistan	Female			1
E	India	Male	1	1	1
F1	Pakistan	Female	1	1	1
F2	Pakistan	Female		1	1
F3	Pakistan	Female		1	1
F4	Pakistan	Female		1	1
F5	Pakistan	Female	1	1	1
F6	Pakistan	Female		1	1
G1	Indonesia	Female			1
G2	Indonesia	Female	1	1	1
G3	Indonesia	Female	1	1	1
H1	Indonesia	Female			1
H2	Indonesia	Female	1	1	1
I	Indonesia	Male	1	1	1
J1	Kuwait	Male			1
J2	Kuwait	Male	1	1	1
J3	Kuwait	Male	1	1	1
K1	Kuwait	Male	1	1	1
K2	Kuwait	Male	1	1	1
K3	Kuwait	Male	1	1	1
L1	Kuwait	Female	1	1	1
L2	Kuwait	Female	1	1	1
L3	Kuwait	Female			1
M-S1	Kuwait	Female	1(not sit)	1	1
M-S2	Kuwait	Female	1	1	1
M-W1	Kuwait	Female	1(not sit)	1	1
M-W2	Kuwait	Female	1	1	1
N	Nigeria/Ghana	female	1	1	1
O	Nigeria/Ghana	Female	1	1	1
P	Nigeria/Ghana	Male	1	1	1
Q	Nigeria/Ghana	Male	1	1	1
R	Nigeria/Ghana	Male	1	1	1
S	Nigeria/Ghana	Female	1	1	1
T	Nigeria/Ghana	Male	1	1	1
U	Nigeria/Ghana	Male	1	1	1
V1	Pakistan	Male	1	1	1
V2	Pakistan	Male	1	1	1
V3	Pakistan	Male	1	1	1
W	China	Female	1	1	1
X1	India	Female	1		1
X2	India	Female	1	1	1
Y1	India	Female	1	1	1
Y2	India	Female	1		1
Z	India	Male	1	1	1
ASTM	US	Female			1
ASTM	US	Male	1	1	1
		totals	39	41	52

Individual Laboratory Test Methods

The experimental work was performed in three separate laboratories. The effects of air movement were investigated at the **Environmental Ergonomics Research Centre (EERC), Design School, Loughborough University (UK)**; static evaporative resistance was established at the **Institute of Textiles and Clothing, Hong Kong Polytechnic University (Hong Kong)** and, finally, the effects of body posture were studied at **EAT, Department of Design Sciences, Lund University (Sweden)**. Each laboratory used different thermal manikins. Below are the descriptions of equipment and methods provided by each laboratory.

Dry heat resistances only were determined in Loughborough and Lund. Dry and evaporative resistances were determined in Hong Kong. Due to the different technology behind the Hong Kong versus the other manikins, different calculations were used for dry heat resistance. These are shown in equation (1) and (4) for the dry manikins and the Hong Kong manikin respectively.

1. EERC, Design School, Loughborough University (UK)

Female ensembles were tested using a female-shaped thermal manikin 'Victoria' (Figure 1) (PT Teknik, Denmark; http://pt-teknik.dk/), which has 20 independent zones (figure 1). Male ensembles were tested with male-shaped manikin 'Newton' (Figure 2) (MTNW, USA; http://thermal.mtnw-usa.com/products/full-body-manikins/newton) made of 32 independent zones (figure 2).

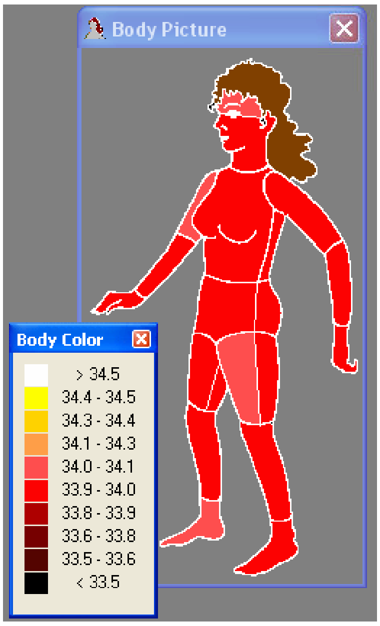

Figure 1; Female shaped Thermal Manikin used at Loughborough University ('Victoria') with zone distribution (right).

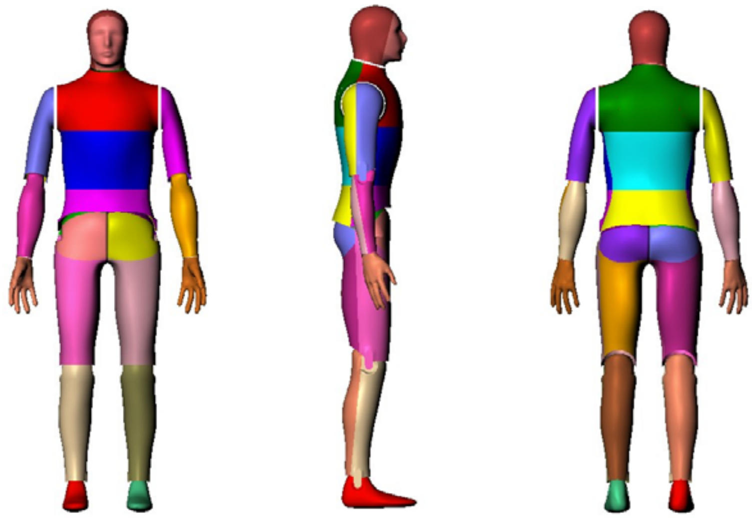

Figure 2; Male shaped Thermal Manikin used at Loughborough University ('Newton') and its 32 control zone structure (right). Each colour indicates an individual zone

For both manikins, heat input or temperature can be controlled and measured. With the skin temperature of the manikin controlled at 34ºC, and a fixed environmental temperature the measured heat loss rate can be used to calculate dry heat resistance of the clothing worn. This measurement is described extensively in ISO 15831:2004 and ISO 9920. Procedures described in this standard were followed unless specifically stated otherwise. Each ensemble was measured at least twice to ensure accuracy, with the mean values being taken. If the discrepancy between measurements is >4% (7% for higher air velocities and movement), a third measurement was taken (ISO 15831).

Dry heat resistance of the ensembles was determined in a 21ºC environment at 50% relative humidity (any variations were recorded and calculations of results accounted for these). Mean radiant temperature was equal to air temperature (confirmed beforehand by black globe measurement).

For the female manikin, due to its technical design the maximal power is lower than that of the male manikin. This meant that at the highest air velocity in some instances the heat loss rate was above the maximal heat input rate. This problem was remedied in two ways: firstly the air temperatures for the measurements were increased to keep the manikin within its control range, and secondly the power supply was replaced allowing a higher voltage and thus heat input to the manufacturers limit (30 volts rather than the standard 24 volt, delivering about 50% more power).

For each ensemble, insulation was measured **in a standing up posture** at the following air velocities: **0.2, 0.4 and 1.0 m.s^{-1}**. A separate wind tunnel was used in the climatic chamber (the chamber has wall to wall air flow in the same direction as the wind tunnel) and the air velocities were accurately determined in a series of pilot tests prior to the main experiments. Actual measured air velocities were: 0.21 ± 0.05; 0.42 ± 0.06 and 1.05 ± 0.08 m.s^{-1} respectively.

Air temperatures, humidity and air velocity were measured using a Testo 454/350 unit (Testo AG, Testostraße 1, 79853 Lenzkirch, Germany) with vane (unidirectional) and hot wire (multidirectional) sensors. The mean radiant temperature was assumed to be equal to the air temperature based on comparisons of air temperature and black globe temperature in the chamber.

The manikin system includes two PT100 sensors (Betatherm 30K5A1B) for air temperature at 0.3 and 1.4 meters height and a Vaisala Humidity sensor (HUMITTER 50U).

The manikin was calibrated according to the procedure described in the ASTM Standard F1291-10. Manikin skin zone sensors were calibrated with the manikin heating deactivated, placed horizontal in a climatic chamber in a turbulent high air velocity (>>4 $m.s^{-1}$) using the certified Testo high precision sensors as reference.

2. EAT, Department of Design Sciences, Lund University (Sweden)

The walking male-shaped thermal manikin 'Tore' is made of plastic with a metal frame inside to support the body parts and for joints. Walking movements are created by pneumatic cylinders fixed to wrists and ankles. Tore is divided into 17 individually-controlled zones: head, chest, back, stomach, buttocks, left and right upper arm, left and right lower arm, left and right hand, left and right thigh, left and right leg, and left and right foot. The surface temperature of the manikin zones' was controlled at 34 ^{o}C.

Air velocity was measured with Swema Air 3000d with SWA03 sensor, Swema AB, Sweden. Ambient air temperature was continuously monitored using three sensors (PT 100, Pico Technology Ltd., UK) positioned adjacent to the ankles, the mid trunk and the head (vertical heights of 0.1, 1.1 and 1.7 m from the soles of the manikin).

The air temperature in the chamber was set to 22.2±0.1 ^{o}C. The mean radiant temperature was assumed to be equal to the air temperature. The air velocity in the chamber was 0.21±0.07 $m.s^{-1}$. The temperatures and heat losses were recorded at 10 second intervals. A minimum of 20 minutes stability was required. Of these, data from the last 10 minutes of the stable state was used for insulation calculation. Calibration and validation trials at Lund University confirmed that this 10 minute period provided repeatable and reliable results. Total insulation values were calculated according to the parallel method (ISO 15831, 2004).

Air velocity distribution details are provided in Appendix E.

Offset calibration of the manikin's surface temperature sensors was carried out in the homogenous conditions (34 ^{o}C) in a warm chamber with the same Pico equipment as stated above. Standard reference clothes of the laboratory and nude manikin were measured before the measurement series to confirm the same results as measured earlier.

The influences of **postures and motion** were studied at Lund University. The three postures were **seated, standing and walking [NOTE: walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward]**. For seated posture the manikin was placed on a mesh chair, and the arms were raised straight in front on insulated supports (Figure 3). During walking the tests followed the recommendation of ISO 15831 (2004) where the step length of 0.65 m at 45 double steps per minute would give an estimated walking speed of about 0.98 $m.s^{-1}$. The wig was not applied during the major testing. Each clothing ensemble was measured independently at least twice, i.e. the manikin was undressed and redressed between independent measurements. If the difference of the independent measurements was above 4 % then an additional test was carried out. However, if the absolute difference in insulation was less than 0.02 $m^{2o}C/W$, especially in the case of very light clothing and strong influence of draping then the 4 % criteria could be exceeded.

Figure 3; Thermal Manikin used at Lund University

3. Institute of Textiles and Clothing, Hong Kong Polytechnic University (Hong Kong)

The male-shaped manikin 'Walter' differs from the others in that it is made of a semi permeable membrane, filled with water, rather than a hard shell like the others. For full details the reader is pointed to detailed publications on this point (Qian and Fan, 2006, 2009). All tests were conducted in the Walter Lab's climatic chamber under the environmental temperature of 20 ± 1ºC and humidity of 40±5%. For technical reasons air velocity for the Walter testing was 0.4 $m.s^{-1}$ with the manikin in standing position, and measured in front of the manikin. Data obtained were corrected for this deviation as will be detailed later. The manikin used is illustrated in Figure 4.

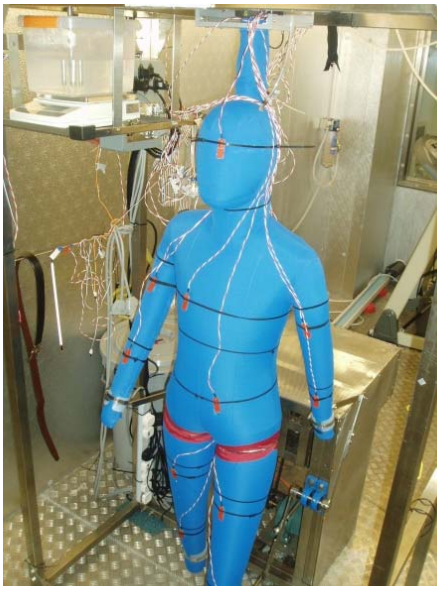

Figure 4; Thermal Manikin used at Hong Kong Polytechnic University

Details of the air velocity distribution are provided in Appendix E.

The climate conditions were set at: Air temperature: 20°C; Relative Humidity: 40%; air Velocity: 0.4m.s^{-1}. Sensors used for the air velocity measurement were by Digitron (Anemometer AF210)

General Methods

Clothing surface area factor measurement f_{cl}

The procedure for the measurement of the clothing surface area factor (surface area of clothed manikin in relation to that of the nude manikin) is described in detail in Appendix D. A Projection of the area factor was used and analyzed in Adobe Photoshop. In general, the procedure follows advice from the literature (Seppanen et al., 1972; Sprague and Munson, 1974; McCullough et al. 2005). Pictures were taken both nude and clothed at a 0 and 90° angle (see Appendix A).

Air insulation I_a

In all laboratories the insulation of the nude manikin was determined for the value of the surface air insulation heat resistance (I_a).

Calculations for I_T and I_{cl}

For the dry manikins (Loughborough and Lund Universities), the dry heat insulation I_T was determined as (Havenith et al. 2002, 2005; Kuklane et al. 2007, 2012):

$$I_T = Dry\ heat\ resistance = \frac{T_{skin} - T_{ambient}}{Dry\ heat\ loss} \quad \left[\frac{Kelvin \cdot square\ meter}{Watt} = m^2.K.W^{-1} \right] \tag{1}$$

The intrinsic clothing insulation I_{cl} was determined as:

$$I_{cl} = I_T - \frac{I_a}{f_{cl}} \quad \left[\frac{Kelvin \cdot square\ meter}{Watt} = m^2.K.W^{-1} \right] \tag{2}$$

Conversion from SI units to Clo units can be performed by:

$$I(clo) = \frac{I(SI\ units)}{0.155} \tag{3}$$

As the wet manikin (Walter, Hong Kong) measures dry and wet heat transfer at the same time the equation for Walter for dry heat resistance is different from equation (1). In this case the thermal insulation (I_T) and moisture vapor resistance ($R_{e,T}$) of clothing was calculated on the same physics principles as in equation (1), but correcting for evaporative heat loss present in this case, using the following formulae as described by Wu et al., 2011. Assuming no interaction of wet and dry heat transfer occurs (no condensation in the clothing; steady state) this will provide identical results to equation (1). In these calculations the heat resistance of the skin is considered negligible:

$$I_T = \frac{A_s(\overline{T}_s - T_a)}{H_s + H_p - H_e} \qquad (4)$$

$$with \quad H_e = \lambda \cdot Q \qquad (5)$$

$$R_{e,T} = \frac{A_s(P_s^* - RH_a P_a^*)}{H_e} - R_{es} \qquad (6)$$

where,

A_s is the total surface area of the manikin,

$\overline{T}_s$ is the area weighted mean skin temperature,

T_a is the mean temperature of the environment,

H_s is the heat supplied to the manikin or the heat generated by the heaters,

H_p is the heat generated by the pumps inside the body, Hp=18.7 Watts.

H_e is the evaporative heat loss from the water evaporation.

λ is the heat of evaporation of water at the skin temperature, λ = 2430 Joules/gram at 34 ^oC.

Q is the “perspiration” rate or water loss per unit time, which is measured automatically through the electronic balance.

P_s^* is the saturated water vapor pressure at the skin temperature,

RH_a the relative humidity of the surrounding environment,

P_a^* the saturated water vapor pressure at the surrounding environment, and

R_{es} is the moisture vapor resistance of the “skin”. R_{es} is predetermined constant and equals to 8.6 m^2Pa/Watts.

I_T: For the final results, measurements of the static insulation were averaged over the three manikins used for testing each ensemble. For the female garment that would be an average of Victoria, Tore and Walter. For the male garments an average of Newton, Tore and Walter.

Calculations for i_m

The observed values for R_e and I_t were used to calculate the clothing vapor permeability index i_m:

$$i_m = \frac{I_T}{L \cdot R_e} \qquad (7)$$

With: L=Lewis Constant = 0.0165 °C.Pa^{-1}.

Calculations for correction factors for movement and wind

Data for the effects of changing air velocity, walking velocity and posture were calculated and will be presented as correction factors, based on the individual measurement data. This allows a more general use compared to presenting actual insulation values. Hence these will all reference back to the mean static standing insulation values at 0.2 m.s^{-1} air velocity using the following correction factors:

$$Corr_{wind\,0.4} = \frac{I_{T,0.4m/s}}{I_{T,0.2m/s}} \quad \text{(non dimensional)} \tag{8}$$

$$Corr_{walk} = \frac{I_{T,\text{walk}}}{I_{T,\text{static}}} \quad \text{(non dimensional)} \tag{9}$$

$$Corr_{sitting} = \frac{I_{T,\text{sitting}}}{I_{T,\text{static}}} \quad \text{(non dimensional)} \tag{10}$$

The walking effect measured is purely the 'pumping effect'. It is a manikin moving in a relative air speed of 0.2 m.s^{-1}. If a person would walk in a still air space, they would generate a relative air speed of the same value as the walking speed. Hence, at 1 m.s^{-1} walking speed this would be a relative air speed of 1 m.s^{-1} too. This combination was not measured. Instead an estimate was made of this effect based on the research of Havenith et al. (1990) and Havenith and Nilsson (2004, 2005) and of Qian & Fan (2006). After evaluation of these corrections it was chosen to base them in the main on the first two references which are also used in ISO 9920.

$$Corr_{wind,walk} I_T{*}{=}e^{\left[-0{,}281\times(v_{ar}-0{,}15)+0{,}044\times(v_{ar}-0{,}15)^2-0{,}492w+0{,}176w^2\right]} \tag{11}$$

As the air velocity was not the same in all laboratories, data for Dry Insulation (I_T) were corrected for deviations based on the correction factors for that same clothing ensemble as measured in Loughborough. This means that values for Walter were multiplied by the ratio of the 0.2/0.4 m.s^{-1} values measured in Loughborough:

$$\text{Walter } I_T \text{ at 0.2 m/s} = \frac{\text{Walter } I_T \text{ at 0.4 m/s}}{Corr_{wind\,0.4}} \; (\mathrm{m^2 \cdot K \cdot W^{-1}}) \tag{12}$$

As the vapor resistance changes differently (stronger) compared to the heat resistance (Havenith et al, 1990; Havenith & Nilsson 2004, 2005), an additional correction factor is required. As vapor resistance was not measured at different air velocities, this correction was based on the work of Havenith et al. (1990[b], 2012), which was adopted in ISO 9920:

$$\text{Walter } R_{e,T} \text{ at 0.2 m/s} = \frac{\text{Walter } R_{e,T} \text{ at 0.4 m/s}}{Corr_{wind\,0.4}} \cdot \frac{Corr_{wind\,0.4} I_T *}{Corr_{wind\,0.4} R_{e,T} *} \quad (m^2 \cdot Pa \cdot W^{-1})$$

$$\text{with :}$$

$$\frac{Corr_{wind\,0.4} I_T *}{Corr_{wind\,0.4} R_{e,T} *} = \text{correction factor ratio for } I_T \text{ versus } R_{et} \text{ taken from ISO 9920/Havenith et al. and Havenith \& Nilsson:} \tag{13}$$

$$Corr_{wind,walk} I_T * = e^{\left[-0{,}281\times(v_{ar}-0{,}15)+0{,}044\times(v_{ar}-0{,}15)^2-0{,}492w+0{,}176w^2\right]}$$

$$Corr_{wind,walk} R_{e,T} * = e^{\left[-0{,}468\times(v_{ar}-0{,}15)+0{,}080\times(v_{ar}-0{,}15)^2-0{,}874\text{v}_w+0{,}358\text{v}_w^{\;2}\right]}$$

$$with : \text{v}_{\text{ar}} = wind\ speed$$

$$and : v_w = walking\ speed$$

The same procedure was used to calculate the correction factor for $R_{e,T}$ at 1 m.s^{-1} and to determine an estimate for the combined effect of walking (pumping effect) and the relative air movement generated by the walking.

Rather than presenting the $R_{e,T}$ values for all conditions it was decided to present the values for the vapor permeability index i_m, as this allows an easier comparison between garments.

$$i_{m,wind=i} = \frac{I_{T,wind=i}}{R_{e,T,wind=i} \cdot L} \tag{14}$$

$$with\ L = \text{Lewis Constant} = 0.0165\ K \cdot Pa^{-1}$$

i_m can then be used to calculate the vapor resistance from the heat resistance:

$$R_{e,T,wind=i} = \frac{1}{i_{m,wind=i} \cdot L} I_{T,wind=i} \tag{15}$$

Results/Discussion

Manikin Comparison

In order to get an impression of the effect of using different manikins for the testing, data obtained on the individual manikins are presented in relation to the mean insulation value over all manikins for that ensemble, following the basic concept behind Bland Altman plots, used for comparing measurements from different instruments (lacking a gold standard). The results indicate a higher than average value for garments measured on the female shape Victoria (Figure 5), while those for Newton, Tore and Walter (Figure 6, Figure 7 and Figure 8) are close to the line of identity with outliers only for the two highest insulative ensembles (including a coat), where the values for Newton are lower than the average and those for Walter are higher than the average. These data points were extensively checked and the data are considered valid suggesting different effects of the coat on the fit of the clothing between the two manikins.

The higher values for Victoria (8.9 % higher on average than Tore, and 7.8% higher than Walter) are consistent with earlier studies comparing a 'Victoria' shape to Tore (Kuklane et al. 2004). In that study, insulation values from the female manikin provided 14 to 17% higher insulation for the same ensemble. Tight clothing showed less difference than loose clothing. The presently-tested clothing is predominantly loose.

All results for the individual ensembles in the static condition are also presented in Figure 9 (female ensembles) and Figure 10 (male ensembles). These graphs also illustrate the higher variation in results for the ensembles with the coat (L3, J3 and K3).

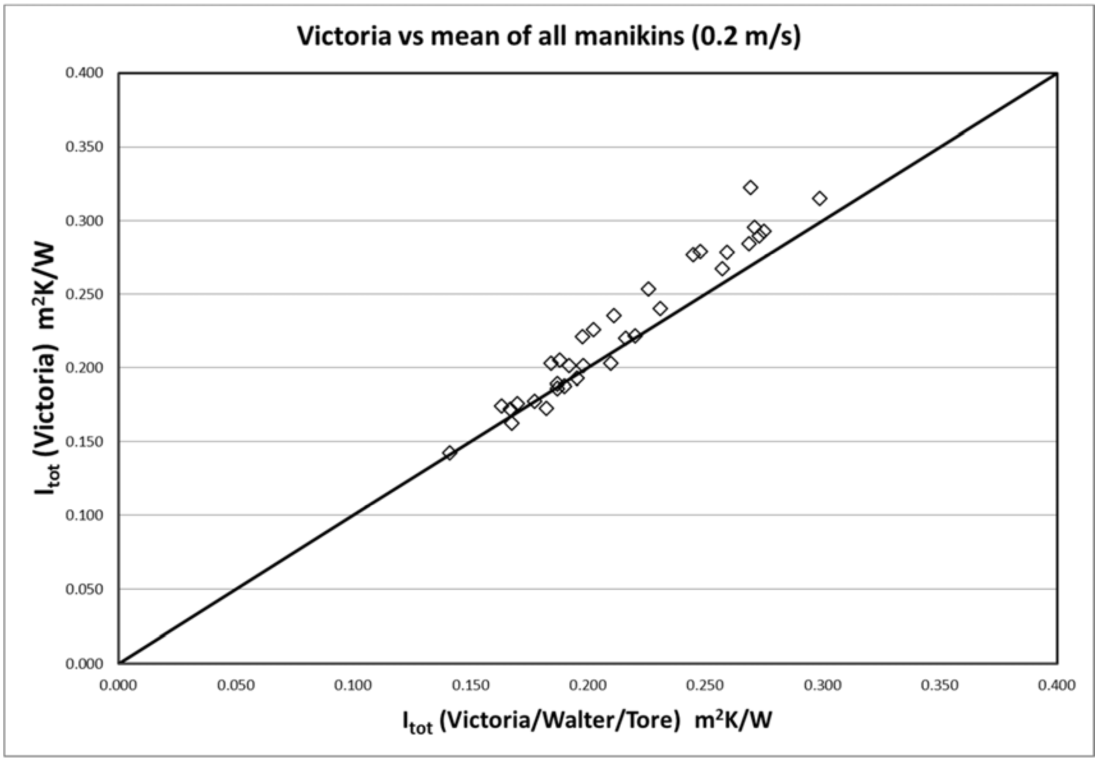

Figure 5; comparison of Female data measured on Victoria to the mean of three manikins: Victoria, Walter and Tore on which the same female ensemble was measured.

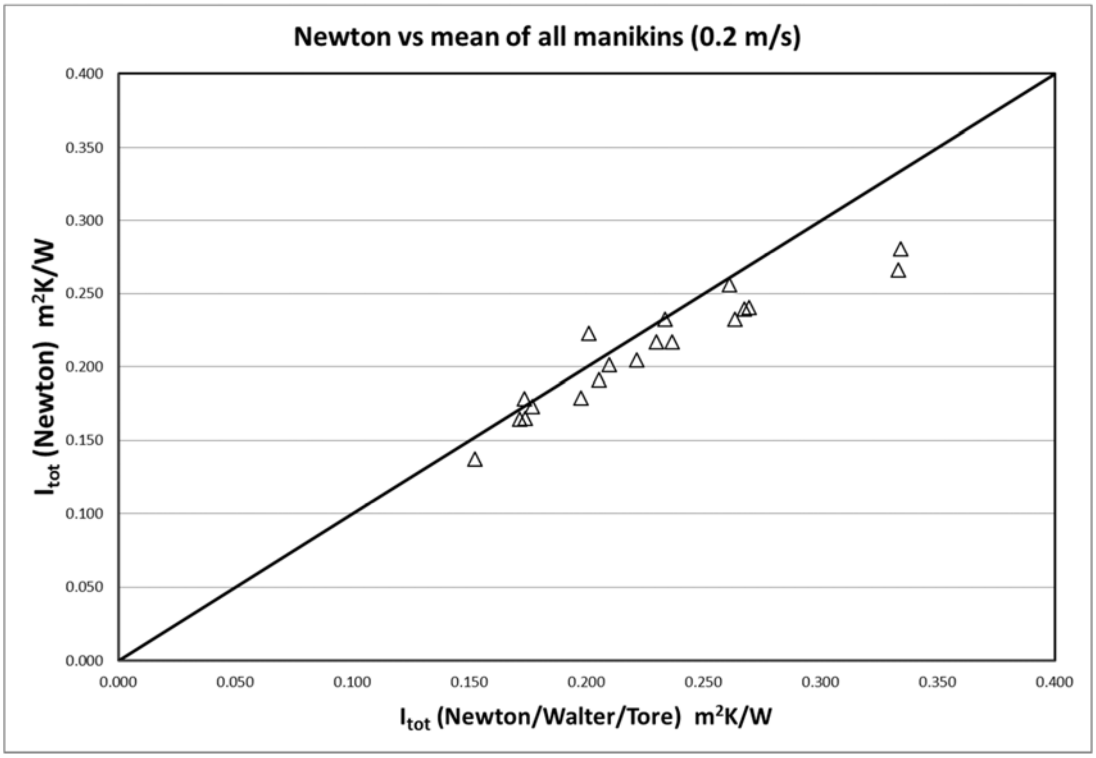

Figure 6; comparison of Male data measured on Newton to the mean of three manikins: Newton, Walter and Tore on which the same male ensemble was measured.

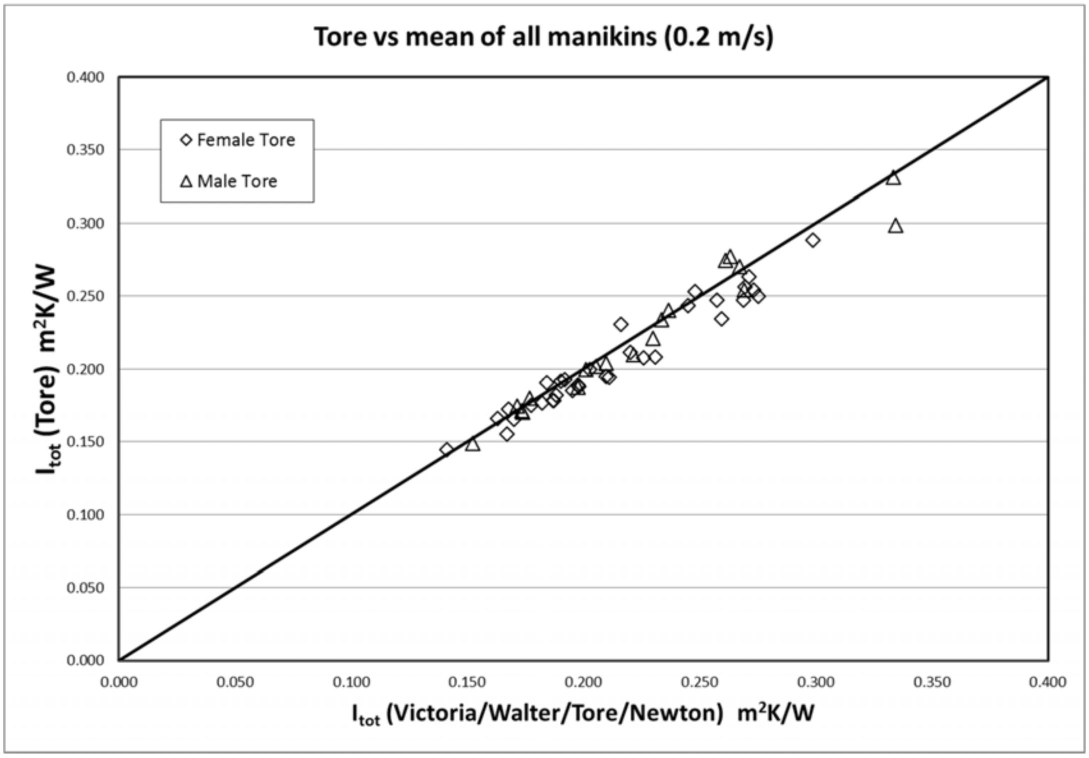

Figure 7; comparison of data measured on Tore to the mean of three manikins: Victoria/Newton, Walter and Tore on which the same ensemble was measured.

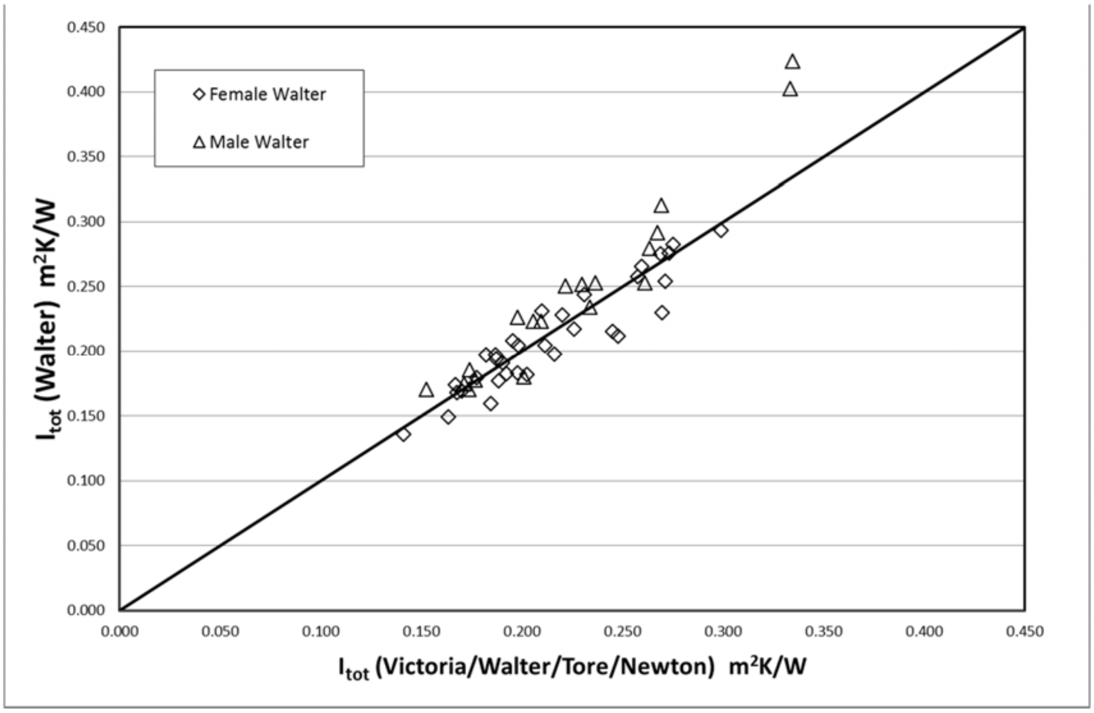

Figure 8; comparison of data for total clothing insulation IT measured on Walter (corrected to 0.2 m/s air speed) to the mean of three manikins: Victoria or Newton, and Walter and Tore on which the same ensemble was measured..

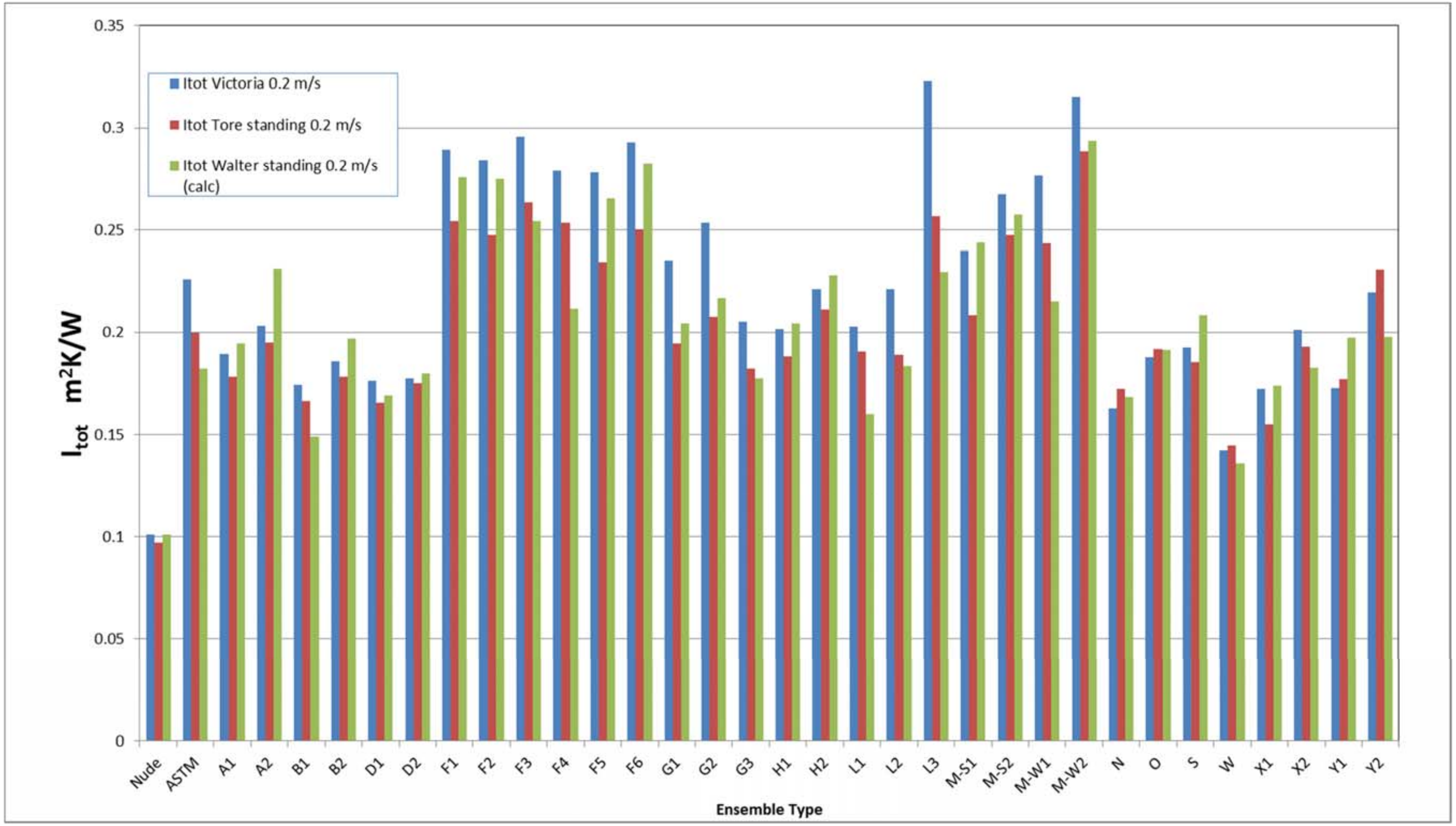

Figure 9; Comparison of measurements of Female ensembles on Victoria, Tore and Walter.

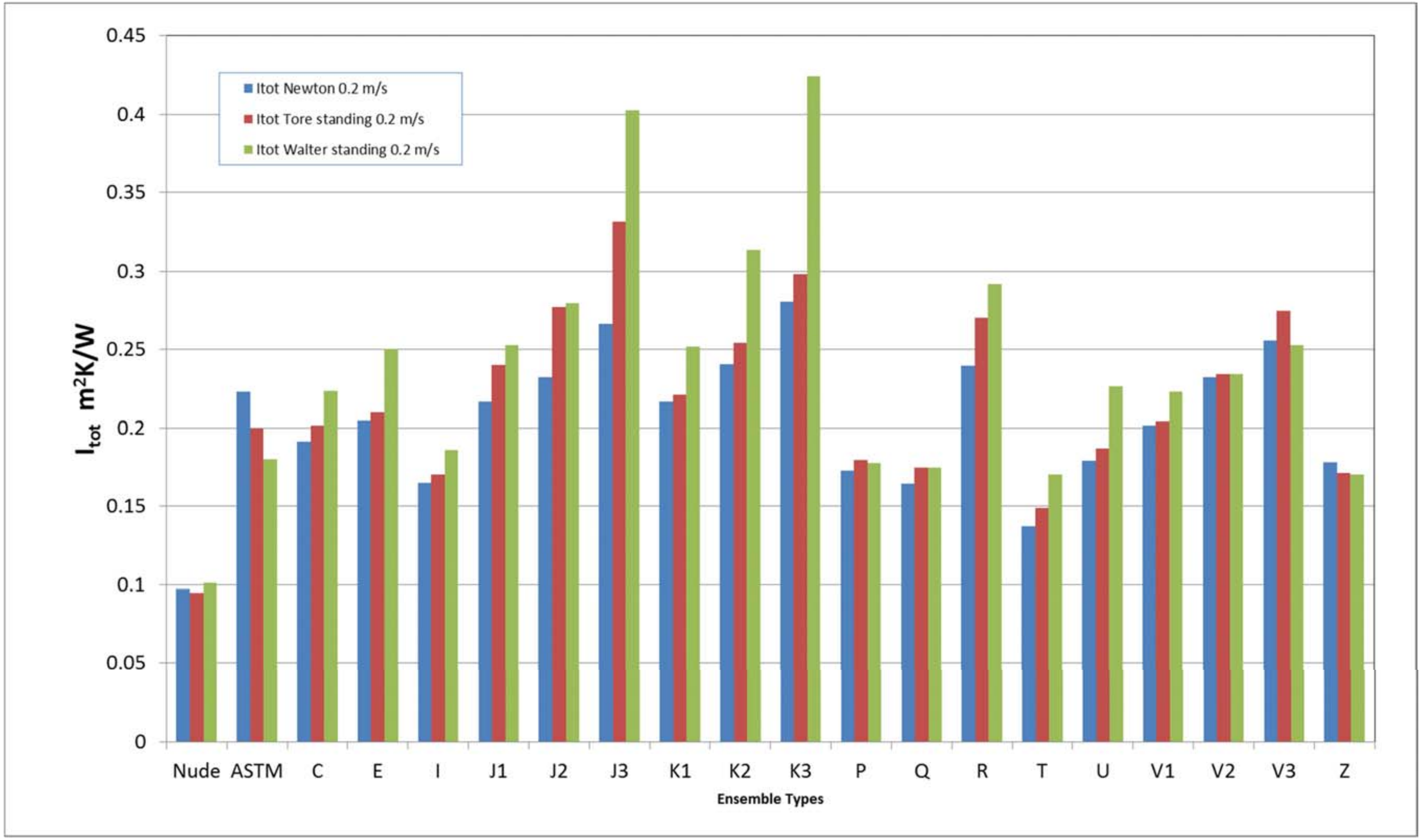

Figure 10; Comparison of measurements of Male ensembles on Newton, Tore and Walter.

Using different manikins to replicate these tests resulted in a range of values for each ensemble. Originally it was considered to use the ASTM calibration ensemble to align the results for the different manikins, however this was reconsidered as the differences between the manikins actually represent a variation that has real life value. The manikin shape is considered to be the main factor in this variation with the female shape manikin (Victoria), consistent with literature (Kuklane et al., 2004), providing slightly higher values than the other manikins. Also, the local conditions in the different climatic chambers may have contributed somewhat to the variability. Having this variability is considered to be a better representation of the variability that is expected when these garments are worn in real life conditions, than if only a single manikin were used, given the expected variability in body shapes of wearers of the ensembles in real life. Thus, while defining insulations for commercial purposes may require an adjustment of the individual manikin's value using a calibration ensemble, for the present purpose this is not the case.

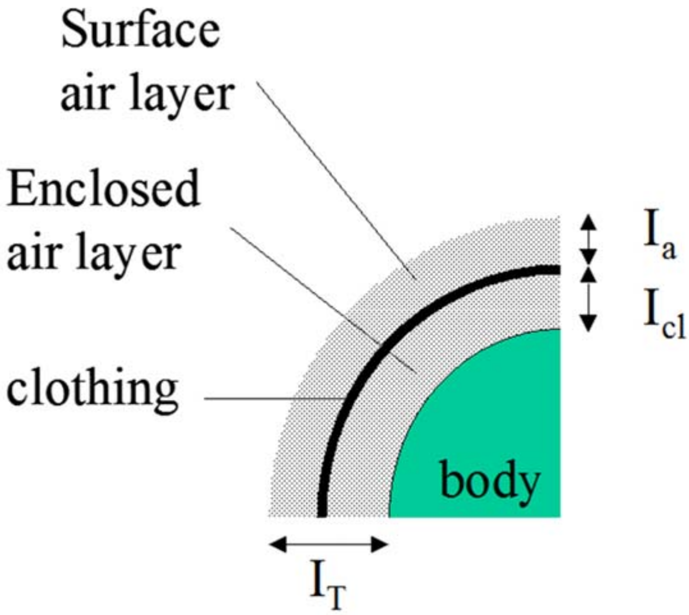

Figure 11, Cylindrical model of total and intrinsic clothing insulation.

Clothing Surface Area Factor

Clothing surface area measurements were based on the photographic method using a frontal and a side picture. A Projection of the area factor was used and analyzed in Adobe Photoshop. In general, the procedure follows advice from the literature (Seppanen et al., 1972; Sprague and Munson, 1974; McCullough et al. 2005). In the past several projects have looked at the area factors determined using different numbers of pictures, and comparing it with other methods like body scanning. The latter method is laborious (folds in the clothing require manual corrections to the datasets). McCullough et al. (2005) showed that for protective clothing, taking a single photograph from the front provided the same information as the more elaborate measurement via 6 pictures from different angles (r^2=0.99, mean square error=0.015). Given the perhaps more unusual and different style of the clothing tested here, it was decided to use both the front and the side picture.

f_{cl} values were used in the established way to calculate the intrinsic clothing insulation I_{cl}. This model of intrinsic and surface air boundary layer insulation is based on a cylindrical model of clothing (Figure 11) which is typical for western style clothing with all clothing worn as cylinders around torso and limbs. Considering the loose fit and the long robe/dress style of many of the garments tested here, this cylindrical model may not be an appropriate model for what is really happening. For example, for the ankle long, wide kameez and abaya garments one would expect air movement underneath these garments, and the still surface air layer may be around the legs rather than all around these outer garments. Creating a physical model of intrinsic and surface layer insulations for such garment styles may therefore not be easy. Also this then would require different models for the ASHRAE 55 standard, which is impractical.

Having calculated the I_{cl} values for these ensembles in the traditional way may not be physically correct, but these can nevertheless be used in the standard as the calculations there use the same method to reconstruct total resistance from I_{cl} and I_a. It is important to ensure that the methods used to calculate I_{cl} from I_T are consistent with those used for calculating heat losses in any models or in the standard. Then, despite the calculations not being physically correct, this will have no bearing on the results.

In the various clothing publications dealing with the f_{cl} factor, prediction equations for f_{cl} are provided. These are based on western clothing. The equation listed in ISO 9920, based on work by McCullough et al. (1985), reads:

-If I_{cl} is expressed in $m^2 \cdot {}^\circ C \cdot W^{-1}$:

$$f_{\mathrm{cl}} = 1{,}00 + 1{,}97 I_{\mathrm{cl}} \tag{16}$$

-If I_{cl} is expressed in *clo*:

$$f_{\mathrm{cl}} = 1{,}00 + 0{,}31 I_{\mathrm{cl}} \tag{17}$$

The application range for which these relations were tested is between 0.2 and 1.7 clo.

For the non-western clothing (Figure 12, Figure 13 and Figure 14), studied in this project, the equations (one with constant fixed to 1.0; the other with a constant allowed to vary from one) would read:

-If I_{cl} is expressed in $m^2 \cdot {}^\circ C \cdot W^{-1}$:

$$f_{\mathrm{cl}} = 1{,}00 + 2.886 I_{\mathrm{cl}} \tag{18}$$

Or:

$$f_{\mathrm{cl}} = 1{,}08 + 2.414 I_{\mathrm{cl}} \tag{19}$$

-If I_{cl} is expressed in *clo*:

$$f_{\mathrm{cl}} = 1{,}00 + 0{,}447 I_{\mathrm{cl}} \tag{20}$$

$$f_{\mathrm{cl}} = 1{,}074 + 0.379 I_{\mathrm{cl}} \tag{21}$$

Both with an adjusted r^2 value of 0.60 (with intercept forced to 1.0, the adjusted r^2 rises to 0.95, though this is equivalent to deleting the constant, thus providing a different type of r^2) see Figure 12.

The Standard Error of the Estimate (SEE) for f_{cl} is 0.106 for these regressions. The application range for which these relations were tested is between 0.4 and 1.74 clo.

Given the quite low r^2 value and high SEE, the authors do not deem this to be a reliable approach and thus it is questionable whether such equations should be added to ISO 9920. However, revisiting the report by McCullough at al. (1985) for western clothing, from which the currently used equation in ISO 9920 is taken, it appears that the uncertainty in those is equivalent to what is found here. For the equation with a constant (i.e. not forced through 1.0 at I_{cl}=0), the adjusted r^2 equals 0.55 and that without a constant equals 0.95 (again, these r^2 values cannot be compared as they are not based on an equivalent calculation). The SEE is between 0.06 and 0.07, which is better than for the current dataset however. Given the low r^2, it is somewhat surprising that this equation is in such widespread use, though as McCullough et al. remark, there are no real alternatives. Nevertheless this issue should be discussed in the ISO committee dealing with the ISO 9920 standard, as no caveat is presented with those equations there.

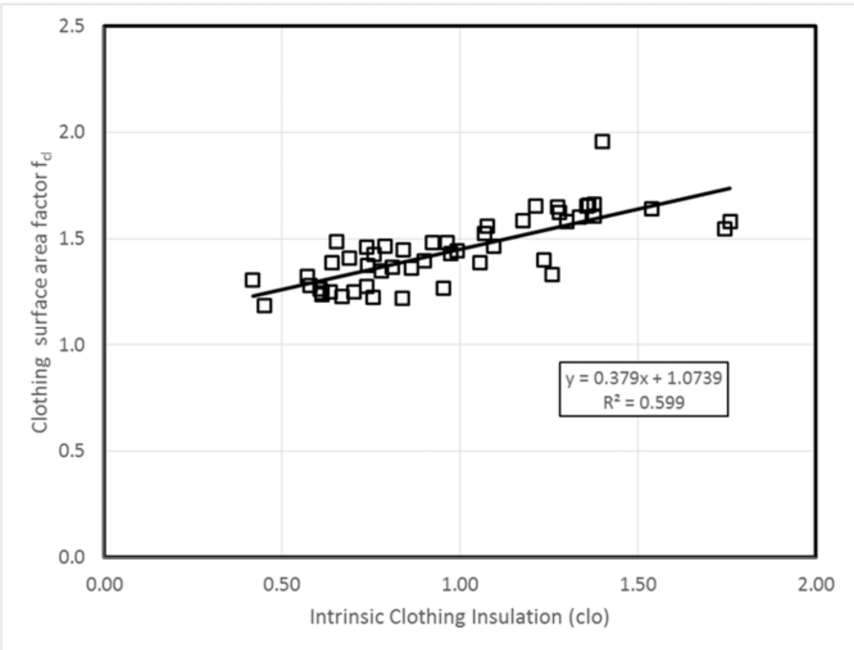

Figure 12, Relationship between clothing area factor *f_{cl}* as measured according to appendix D, and intrinsic clothing insulation *I_{cl}* calculated using this *f_{cl}* value (see equation (2)).

Averaged Data for Ensembles

The final data for the different ensembles for total and intrinsic clothing insulation, averaged over all tests with all manikins used, are presented in Table 2 and Table 3.

Table 2, average values for Female clothing insulation (total and intrinsic) and f_{cl}, as well as standard deviation (%) over the three laboratories. f_{cl} values were measured using a photographic method as described in appendix D. I_{cl} was calculated using I_T and f_{cl} values according to equation (2). n=number of different manikins included in data in this line. Last two columns provide I_{cl} in SI units and in clo units. M=measured, C=Calculated

			Means of n laboratories								
Ensemble	Country	Gender	IT total (m2.K/W)	IT total (clo)	n (It)	% SD IT total	Ia (m2.K/W)	fcl	Icl (m2.K/W)	Icl (clo)	im value 0.2 m/s (n.d)
Measured/ Calculated			M	M		M	M	M	C	C	C
Nude		F	0.099	0.6	3	3.58	0.099	1.00	0.00	0.00	
ASTM	USA	F	0.203	1.3	3	10.82	0.099	1.23	0.12	0.79	0.28
A1	Pakistan	F	0.187	1.2	3	4.45	0.099	1.43	0.12	0.76	0.31
A2	India	F	0.210	1.4	3	9.08	0.099	1.48	0.14	0.92	0.36
B1	India	F	0.163	1.1	3	7.80	0.099	1.33	0.09	0.57	0.32
B2	India	F	0.187	1.2	3	5.07	0.099	1.37	0.11	0.74	0.37
D1	Pakistan	F	0.170	1.1	3	3.18	0.099	1.39	0.10	0.64	0.31
D2	Pakistan	F	0.177	1.1	3	1.32	0.099	1.41	0.11	0.69	0.32
F1	Pakistan	F	0.273	1.8	3	6.43	0.099	1.67	0.21	1.38	0.31
F2	Pakistan	F	0.269	1.7	3	7.01	0.099	1.60	0.21	1.33	0.33
F3	Pakistan	F	0.271	1.7	3	7.88	0.099	1.66	0.21	1.36	0.29
F4	Pakistan	F	0.248	1.6	3	13.61	0.099	1.65	0.19	1.21	0.27
F5	Pakistan	F	0.259	1.7	3	8.63	0.099	1.63	0.20	1.28	0.33
F6	Pakistan	F	0.275	1.8	3	7.96	0.099	1.61	0.21	1.38	0.33
G1	Indonesia	F	0.211	1.4	3	10.02	0.099	1.22	0.13	0.84	0.30
G2	Indonesia	F	0.226	1.5	3	10.68	0.099	1.27	0.15	0.95	0.30
G3	Indonesia	F	0.188	1.2	3	7.87	0.099	1.25	0.11	0.70	0.29
H1	Indonesia	F	0.198	1.3	3	4.35	0.099	1.37	0.13	0.81	0.29
H2	Indonesia	F	0.220	1.4	3	3.77	0.099	1.43	0.15	0.97	0.31
L1	Kuwait	F	0.184	1.2	3	12.00	0.099	1.23	0.10	0.67	0.32
L2	Kuwait	F	0.198	1.3	3	10.32	0.099	1.23	0.12	0.76	0.35
L3	Kuwait	F	0.270	1.7	3	17.70	0.099	1.33	0.20	1.26	0.29
M-S1	Kuwait	F	0.231	1.5	3	8.38	0.099	1.56	0.17	1.08	0.35
M-S2	Kuwait	F	0.257	1.7	3	3.87	0.099	1.65	0.20	1.27	0.33
M-W1	Kuwait	F	0.245	1.6	3	12.47	0.099	1.59	0.18	1.18	0.30
M-W2	Kuwait	F	0.299	1.9	3	4.69	0.099	1.64	0.24	1.54	0.35
N	Nigeria/Ghana	F	0.168	1.1	3	2.88	0.099	1.49	0.10	0.65	0.33
O	Nigeria/Ghana	F	0.190	1.2	3	1.15	0.099	1.47	0.12	0.79	0.33
S	Nigeria/Ghana	F	0.194	1.3	3	6.88	0.099	1.35	0.12	0.78	0.40
W	China	F	0.141	0.9	3	2.90	0.099	1.31	0.06	0.42	0.40
X1	India	F	0.167	1.1	3	6.23	0.099	1.28	0.09	0.58	0.36
X2	India	F	0.192	1.2	3	4.86	0.099	1.28	0.11	0.74	0.32
Y1	India	F	0.182	1.2	3	7.28	0.099	1.46	0.11	0.74	0.33
Y2	India	F	0.216	1.4	3	7.80	0.099	1.48	0.15	0.96	0.30

Table 3, average values for Male clothing insulation (total and intrinsic) and f_{cl}, as well as standard deviation (%) over the three laboratories. f_{cl} values were measured using a photographic method as described in appendix D. I_{cl} was calculated using I_T and f_{cl} values according to equation (2). n=number of different manikins included in data in this line). Last two columns provide I_{cl} in SI units and in clo units. M=measured, C=Calculated

			Means of n laboratories								
Ensemble	Country	Gender	IT total (m2.K/W)	IT total (clo)	n (It)	% SD IT total	Ia (m2.K/W)	fcl	Icl (m2.K/W)	Icl (clo)	im value 0.2 m/s (n.d)
Measured/ Calculated			M	M		M	M	M	C	C	C
Nude		M	0.098	0.6	3	3.14	0.098	1.00	0.00	0.00	
ASTM	USA	M	0.192	1.2	3	5.59	0.098	1.25	0.11	0.74	0.28
C	Pakistan	M	0.205	1.3	3	7.93	0.098	1.36	0.13	0.86	0.35
E	India	M	0.222	1.4	3	11.32	0.098	1.45	0.15	0.99	0.35
I	Indonesia	M	0.174	1.1	3	6.23	0.098	1.24	0.09	0.61	0.35
J1	Kuwait	M	0.237	1.5	3	7.72	0.098	1.47	0.17	1.10	0.28
J2	Kuwait	M	0.263	1.7	3	10.11	0.098	1.58	0.20	1.30	0.26
J3	Kuwait	M	0.333	2.2	3	20.41	0.098	1.55	0.27	1.74	0.30
K1	Kuwait	M	0.230	1.5	3	8.27	0.098	1.53	0.17	1.07	0.29
K2	Kuwait	M	0.269	1.7	3	14.32	0.098	1.66	0.21	1.36	0.30
K3	Kuwait	M	0.334	2.2	3	23.41	0.098	1.58	0.27	1.76	0.34
P	Nigeria/Ghana	M	0.177	1.1	3	1.96	0.098	1.25	0.10	0.64	0.28
Q	Nigeria/Ghana	M	0.171	1.1	3	3.42	0.098	1.26	0.09	0.61	0.31
R	Nigeria/Ghana	M	0.267	1.7	3	9.82	0.098	1.96	0.22	1.40	0.42
T	Nigeria/Ghana	M	0.152	1.0	3	11.05	0.098	1.19	0.07	0.45	0.54
U	Nigeria/Ghana	M	0.198	1.3	3	12.83	0.098	1.45	0.13	0.84	0.39
V1	Pakistan	M	0.210	1.4	3	5.65	0.098	1.40	0.14	0.90	0.34
V2	Pakistan	M	0.234	1.5	3	0.42	0.098	1.39	0.16	1.06	0.31
V3	Pakistan	M	0.261	1.7	3	4.54	0.098	1.40	0.19	1.23	0.27
Z	India	M	0.173	1.1	3	2.53	0.098	1.25	0.09	0.61	0.32

Correction Factors for effect of Air velocity, Posture, Movement

Figures showing the correction factors for air velocity, sitting and walking for all ensembles are shown in Figure 15 to Figure **17**. Results are also presented in table form in Table 5 to Table 6. Here, SI values are presented for total, air and intrinsic insulation, as well as the correction factors for air velocity, walking and sitting, and the values for the permeability index for the different air velocities. Mean corrections for male and female ensembles are quite similar.

Correction factors rather than actual insulation and vapor resistance values are presented. The reason for this is that these corrections were measured in only one laboratory and hence the actual values would only be applicable to one set of tests in one lab. By calculating relative values, the value under different air movement or posture can be calculated using the mean value of the three laboratories as baseline.

Comparing the average correction factors observed in these tests to those developed by Havenith and Nilsson (2004, 2005), Havenith et al. (2012) (adopted for ISO 9920) and those developed by Qian & Fan, 2006 (Table 4), it can be seen that the presently-measured correction factors are stronger, i.e. on average, the insulation values are reduced more by air velocity for non-western than for western ensembles. This was anticipated based on the loose fit of the clothing (Havenith et al. 1990[a]) and the mostly higher air permeability (Havenith and Nilsson, 2004, 2005).

Table 4, Comparison of correction factors for wind and movement between present data for non-western ensembles and data from literature for western ensembles. [NOTE: In the present study walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward]. (All corrections relative to the 0.2 m.s^{-1} static value).

	Static Relative Air Velocity 0.4 m.s^{-1}	Static, Relative Air Velocity 1.0 m.s^{-1}	Walk 1.0 m.s^{-1} Relative Air Velocity 0.2 m.s^{-1}	Walk 1.0 m.s^{-1} Relative Air Velocity 1.0 m.s^{-1}
I_T-Havenith, Nilsson 2004, 2005/ISO	0.95	0.82	0.77	0.60
I_T-Qian, Fan, Yu 2006	0.95	0.82	0.70	0.59
I_T–this study, non-western	0.87	0.65	0.66	-

Regional Insulation Values

Further, three manikins (Victoria, Newton and Tore) also provided regional insulation data. These are presented in Table 7 to Table 12. For Tore, only 0.2 m.s^{-1} air velocity values were obtained (standing, sitting and walking). The presented values are the averages of the static measurements for either Victoria & Tore (female ensembles) or Newton & Tore (male ensembles). As for the higher air velocity values only Victoria & Newton data were available, and correction factors were calculated to be applied on the mean values at 0.2 m.s^{-1}, rather than showing the absolute values. The latter would be inconsistent as in that case values at 0.2 m.s^{-1} would be from 2 manikins, while those at 0.4 and 1.0 m.s^{-1} would be from just one manikin. Similarly, for sitting and walking correction factors only are displayed.

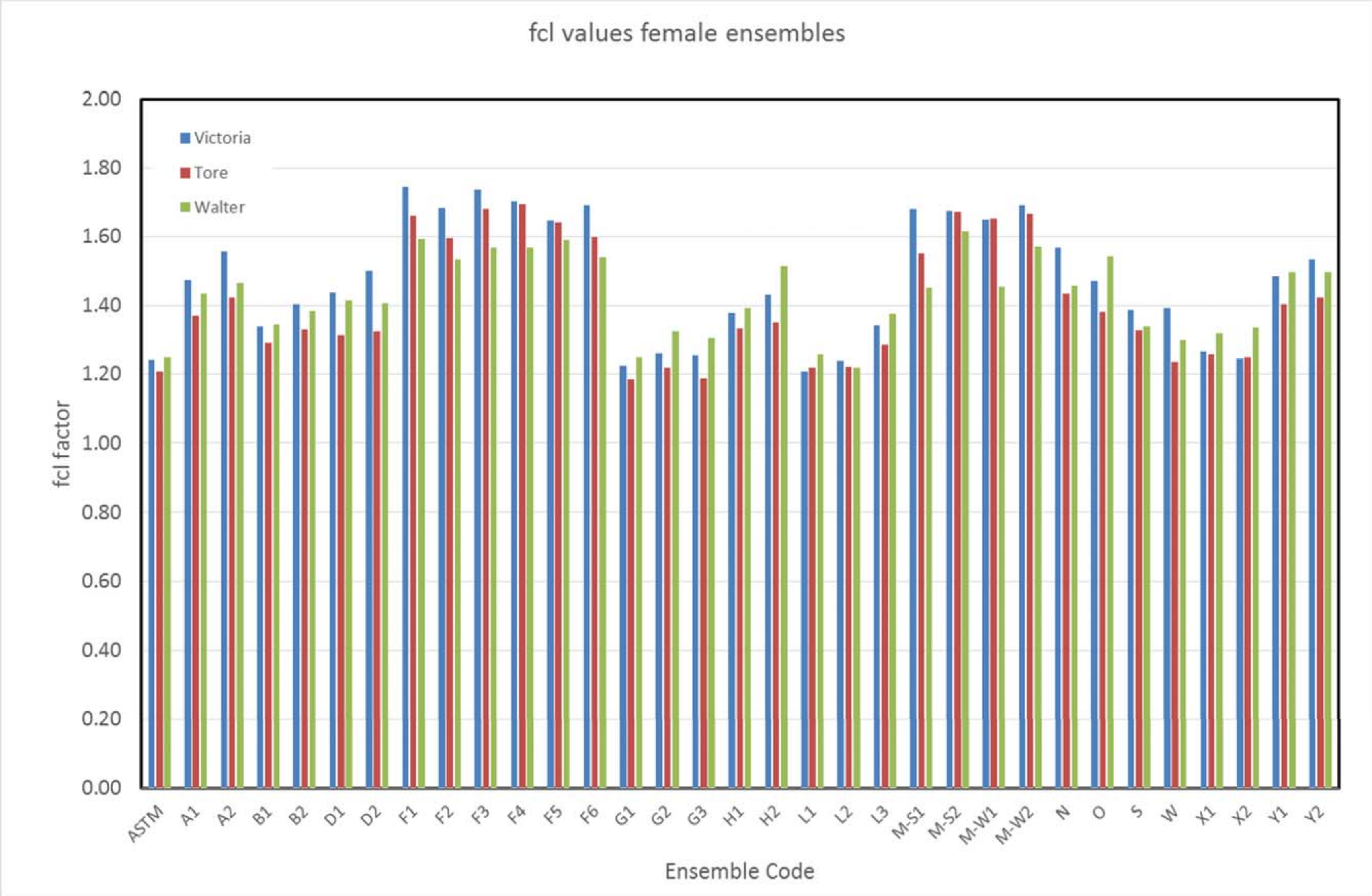

Figure 13, Comparison of measurements of f_{cl} for Female ensembles on Victoria, Tore and Walter

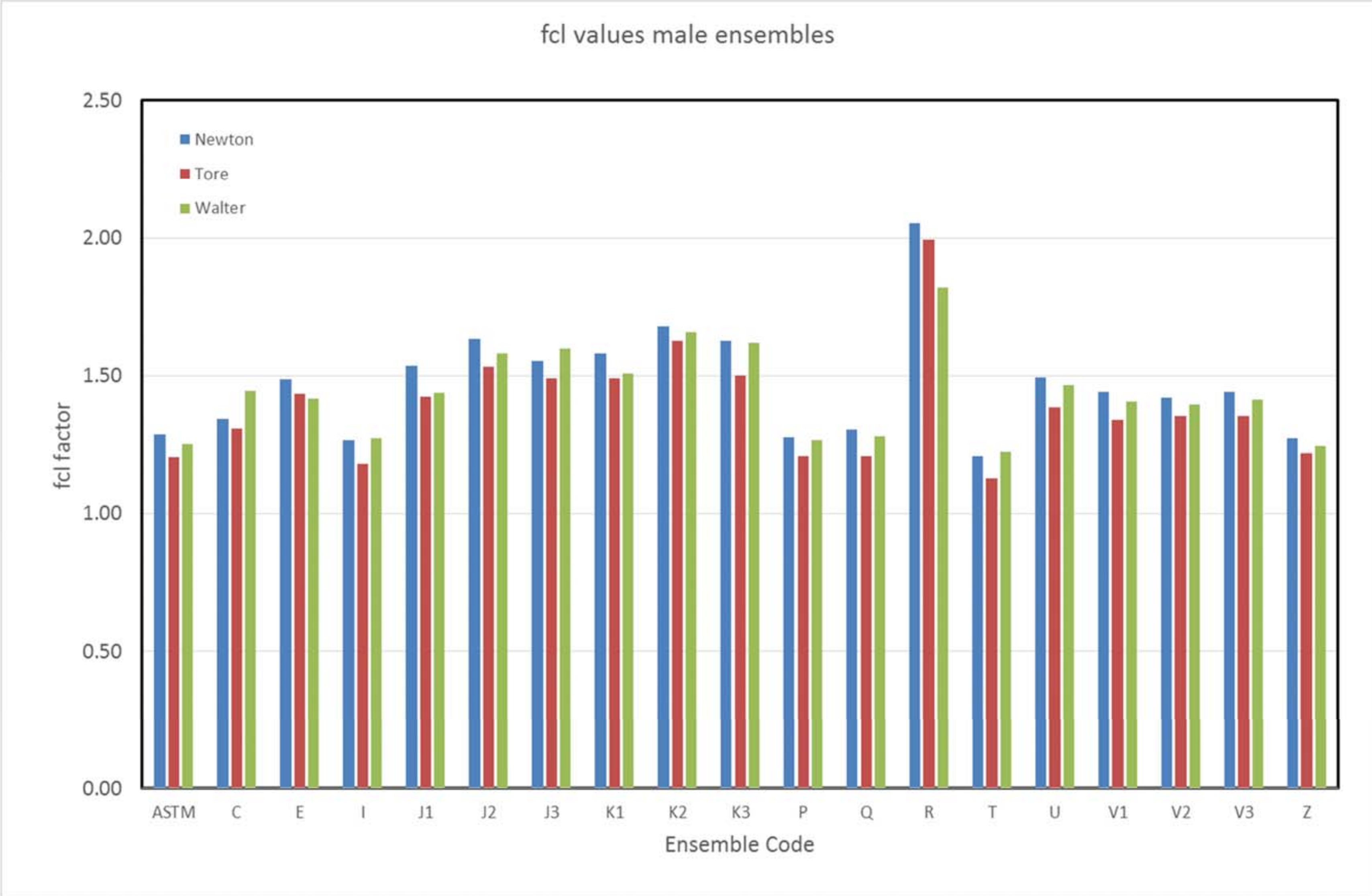

Figure 14, Comparison of measurements of f_{cl} of male ensembles on Newton, Tore and Walter

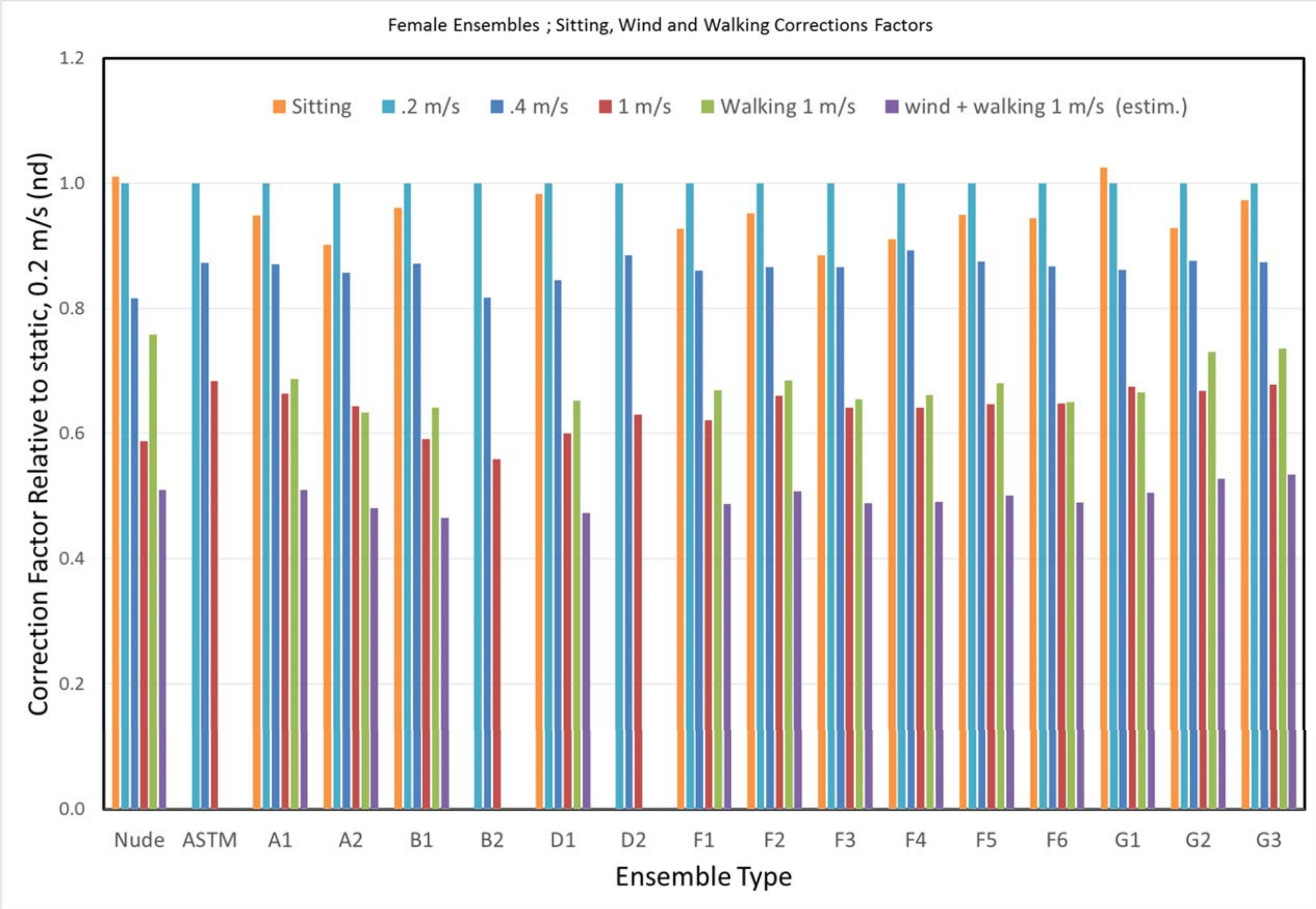

Figure 15; Correction Factors for the effects of air velocity (Victoria/Newton), and walking and sitting (Tore) on total clothing insulation i_T. To obtain the insulation value for sitting, walking or different air speeds, the static 0.2 m.s^{-1} value needs to be multiplied with the respective factor shown here. [NOTE: walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward; an estimate of the combined effect is provided based on data by Havenith & Nilsson, 2004].

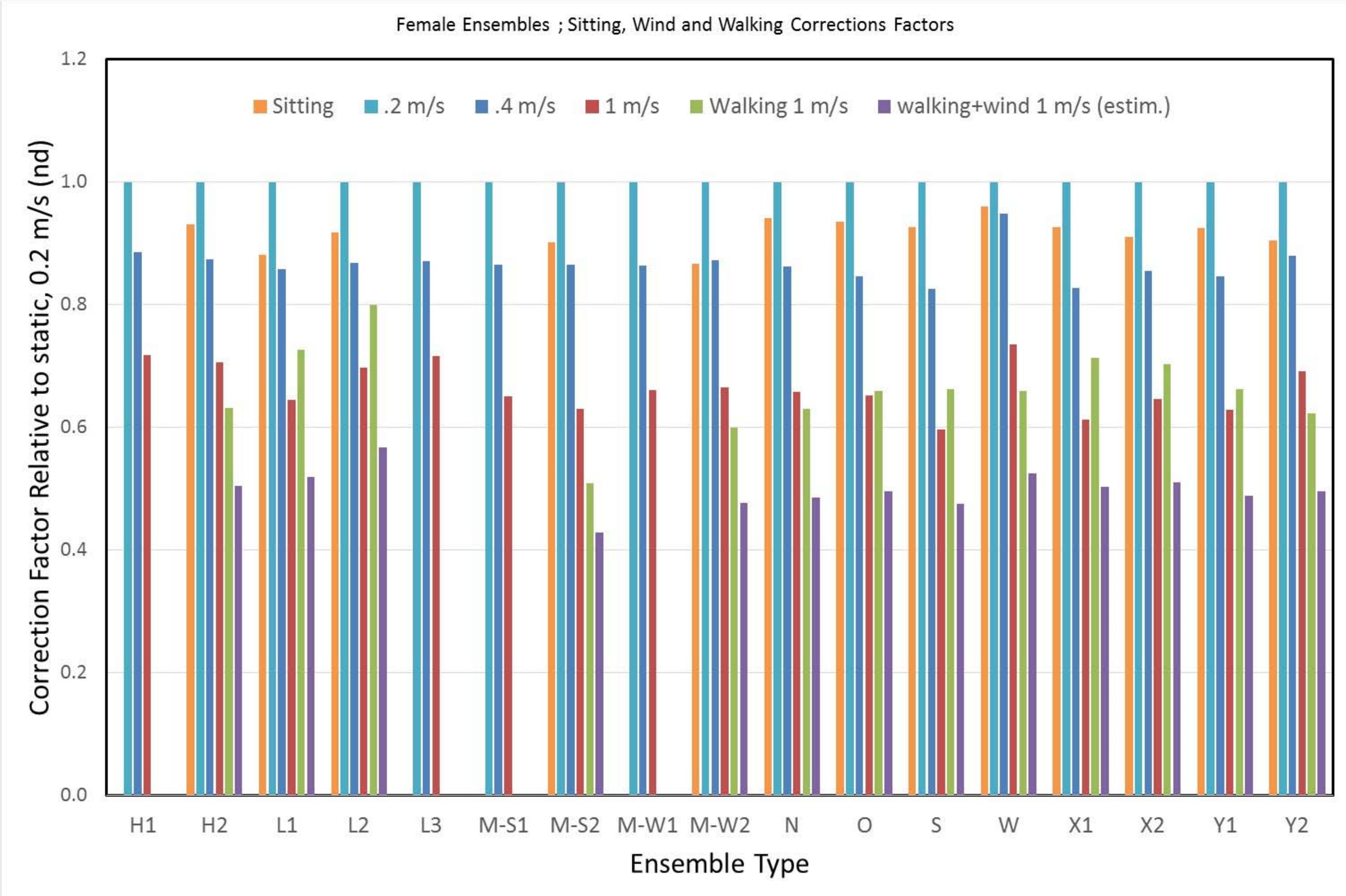

Figure 16; Correction Factors for the effects of air velocity (Victoria/Newton), and walking and sitting (Tore) on total clothing insulation i_T. To obtain the insulation value for sitting, walking or different air speeds, the static 0.2 m.s^{-1} value needs to be multiplied with the respective factor shown here. [NOTE: walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward; an estimate of the combined effect is provided based on data by Havenith & Nilsson, 2004].

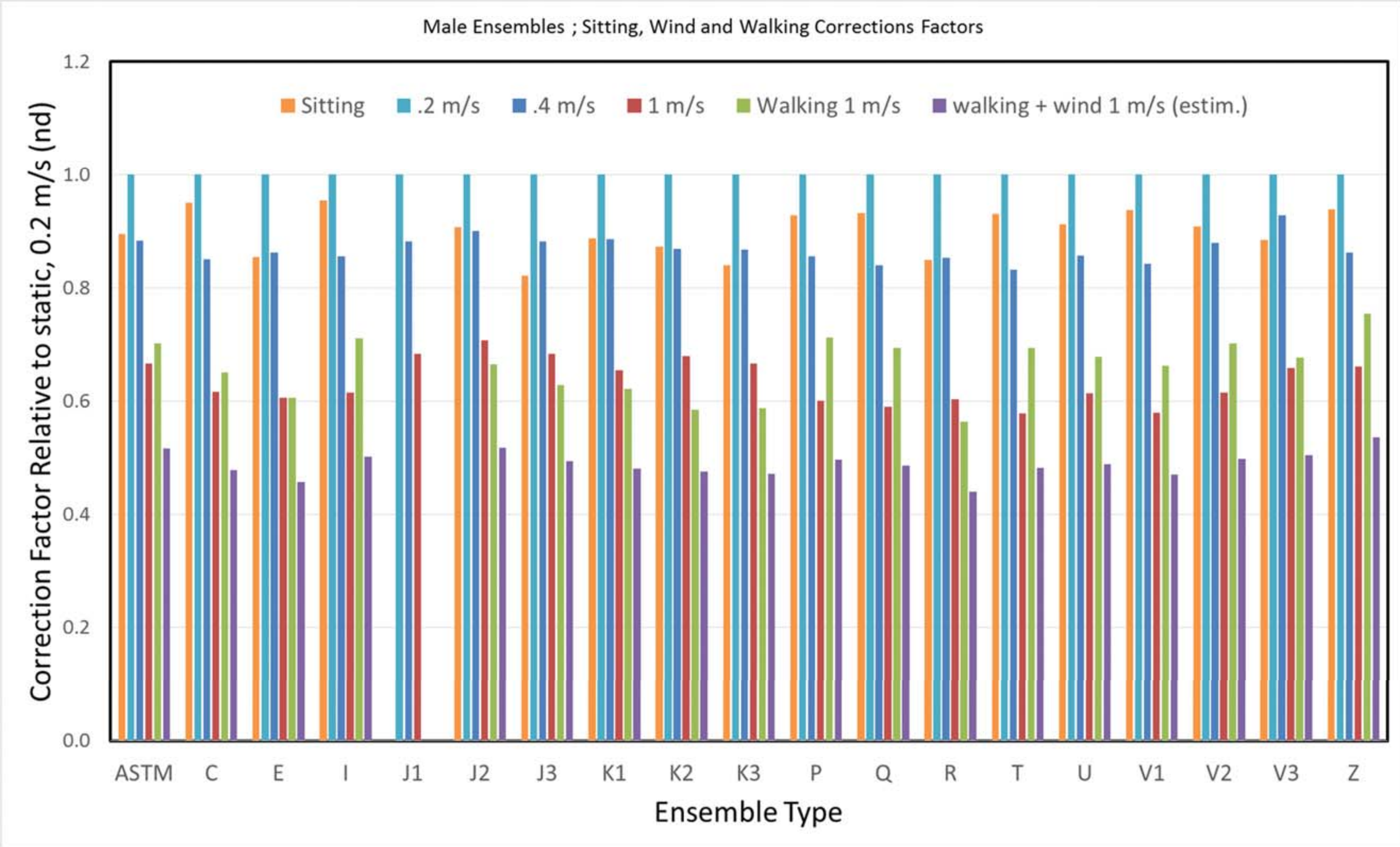

Figure 17; Correction Factors for the effects of air velocity (Victoria/Newton), and walking and sitting (Tore) on total clothing insulation i_T. To obtain the insulation value for sitting, walking or different air speeds, the static 0.2 m.s^{-1} value needs to be multiplied with the respective factor shown here. [NOTE: walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward; an estimate of the combined effect is provided based on data by Havenith & Nilsson, 2004].

Table 5, correction factors for different air velocities, posture and movement on intrinsic and total insulation and the permeability index i_m, for female garment ensembles. To obtain the insulation value for sitting, walking or different air speeds, the static 0.2 m.s^{-1} value needs to be multiplied with the respective factor shown here. These i_m values are calculated from the wind speed corrected values of I_T and R_e. The latter I_T data were measured. The R_e data were estimated from the measurement at 0.4 m.s^{-1}, using the correction equations given in ISO 9920, which are based on the work by Havenith et al., 1990. [NOTE: walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward; an estimate of the combined effect is provided based on data by Havenith & Nilsson, 2004]. M=measured, C=Calculated, E=estimated

			IT	IT	IT	IT	IT	IT	total	total	total	Icl	Icl	Icl	Icl	Icl
			IT	IT	IT	IT	IT	IT	total	total	total	Icl	Icl	Icl	Icl	Icl
Ensemble	Country	Gender	correction Coefficient 0.2 m/s (n.d.)	Correction Coefficient 0.4 m/s (n.d)	Correction Coefficient 1.0 m/s (n.d)	Correction Coefficient sitting (n.d)	Correction Coefficient walking (n.d)	correction walking+wind (n.d.)	im value 0.2 m/s (n.d)	im value 0.4 m/s (n.d)	im value 1 m/s (n.d)	correction Coefficient 0.2 m/s (n.d.)	Correction Coefficient 0.4 m/s (n.d)	Correction Coefficient 1.0 m/s (n.d)	Correction Coefficient sitting (n.d)	Correction Coefficient walking (n.d)
Measured/ Calculated			M	M	M	M	M	E	C	M	C	C	C	C	C	C
Nude		F	1.00	0.82	0.59	1.01	0.76	0.51								
ASTM	USA	F	1.00	0.87	0.68				0.28	0.29	0.32	1.00	0.90	0.74		
A1	Pakistan	F	1.00	0.87	0.66	0.95	0.69	0.51	0.31	0.32	0.35	1.00	0.90	0.71	0.91	0.64
A2	India	F	1.00	0.86	0.64	0.90	0.63	0.48	0.36	0.37	0.40	1.00	0.88	0.67	0.84	0.57
B1	India	F	1.00	0.87	0.59	0.96	0.64	0.47	0.32	0.33	0.36	1.00	0.91	0.59	0.92	0.55
B2	India	F	1.00	0.82	0.56				0.37	0.38	0.42	1.00	0.82	0.54		
D1	Pakistan	F	1.00	0.85	0.60	0.98	0.65	0.47	0.31	0.32	0.35	1.00	0.85	0.60	0.96	0.57
D2	Pakistan	F	1.00	0.88	0.63				0.32	0.33	0.36	1.00	0.93	0.66		
F1	Pakistan	F	1.00	0.86	0.62	0.93	0.67	0.49	0.31	0.32	0.35	1.00	0.87	0.63	0.90	0.64
F2	Pakistan	F	1.00	0.87	0.66	0.95	0.68	0.51	0.33	0.34	0.37	1.00	0.88	0.68	0.93	0.66
F3	Pakistan	F	1.00	0.86	0.64	0.88	0.65	0.49	0.29	0.31	0.33	1.00	0.88	0.65	0.85	0.63
F4	Pakistan	F	1.00	0.89	0.64	0.91	0.66	0.49	0.27	0.28	0.31	1.00	0.91	0.65	0.88	0.63
F5	Pakistan	F	1.00	0.87	0.65	0.95	0.68	0.50	0.33	0.34	0.37	1.00	0.89	0.66	0.93	0.65
F6	Pakistan	F	1.00	0.87	0.65	0.94	0.65	0.49	0.33	0.34	0.38	1.00	0.88	0.66	0.92	0.62
G1	Indonesia	F	1.00	0.86	0.67	1.03	0.67	0.51	0.30	0.31	0.34	1.00	0.89	0.72	1.04	0.60
G2	Indonesia	F	1.00	0.88	0.67	0.93	0.73	0.53	0.30	0.32	0.34	1.00	0.90	0.70	0.88	0.71
G3	Indonesia	F	1.00	0.87	0.68	0.97	0.74	0.53	0.29	0.30	0.32	1.00	0.91	0.74	0.94	0.72
H1	Indonesia	F	1.00	0.89	0.72				0.29	0.30	0.33	1.00	0.93	0.79		
H2	Indonesia	F	1.00	0.87	0.71	0.93	0.63	0.50	0.31	0.32	0.35	1.00	0.90	0.76	0.89	0.57
L1	Kuwait	F	1.00	0.86	0.64	0.88	0.73	0.52	0.32	0.33	0.36	1.00	0.89	0.68	0.79	0.71
L2	Kuwait	F	1.00	0.87	0.70	0.92	0.80	0.57	0.35	0.37	0.40	1.00	0.90	0.76	0.86	0.83
L3	Kuwait	F	1.00	0.87	0.72				0.29	0.30	0.33	1.00	0.89	0.75		
M-S1	Kuwait	F	1.00	0.87	0.65				0.35	0.36	0.40	1.00	0.88	0.67		
M-S2	Kuwait	F	1.00	0.87	0.63	0.90	0.51	0.43	0.33	0.34	0.37	1.00	0.88	0.64	0.87	0.43
M-W1	Kuwait	F	1.00	0.86	0.66				0.30	0.31	0.34	1.00	0.88	0.68		
M-W2	Kuwait	F	1.00	0.87	0.67	0.87	0.60	0.48	0.35	0.36	0.39	1.00	0.89	0.68	0.83	0.56
N	Nigeria/Ghana	F	1.00	0.86	0.66	0.94	0.63	0.49	0.33	0.34	0.38	1.00	0.89	0.70	0.90	0.55
O	Nigeria/Ghana	F	1.00	0.85	0.65	0.94	0.66	0.50	0.33	0.34	0.38	1.00	0.86	0.69	0.89	0.60
S	Nigeria/Ghana	F	1.00	0.83	0.60	0.93	0.66	0.48	0.40	0.41	0.45	1.00	0.83	0.60	0.87	0.60
W	China	F	1.00	0.95	0.74	0.96	0.66	0.53	0.40	0.41	0.45	1.00	1.09	0.89	0.90	0.54
X1	India	F	1.00	0.83	0.61	0.93	0.71	0.50	0.36	0.38	0.41	1.00	0.84	0.64	0.85	0.67
X2	India	F	1.00	0.86	0.65	0.91	0.70	0.51	0.32	0.34	0.37	1.00	0.88	0.69	0.84	0.67
Y1	India	F	1.00	0.85	0.63	0.92	0.66	0.49	0.33	0.34	0.37	1.00	0.87	0.66	0.87	0.60
Y2	India	F	1.00	0.88	0.69	0.90	0.62	0.50	0.30	0.31	0.34	1.00	0.91	0.74	0.86	0.57
mean	(nude excluded)	F	1.000	0.866	0.653	0.931	0.666	0.498	0.324	0.336	0.366	1.000	0.891	0.686	0.890	0.619
sd	(nude excluded)	F	0.000	0.022	0.038	0.034	0.053	0.026	0.031	0.032	0.035	0.000	0.043	0.065	0.048	0.076

Table 6, correction factors for different air velocities, posture and movement on intrinsic and total insulation and the permeability index i_m, for female garment ensembles. To obtain the insulation value for sitting, walking or different air speeds, the static 0.2 m.s^{-1} value needs to be multiplied with the respective factor shown here. These i_m values are calculated from the wind speed corrected values of I_T and R_e. The latter I_T data were measured. The R_e data were estimated from the measurement at 0.4 m.s^{-1}, using the correction equations given in ISO 9920, which are based on the work by Havenith et al., 1990. [NOTE: walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward; an estimate of the combined effect is provided based on data by Havenith & Nilsson, 2004]. M=measured, C=Calculated, E=estimated

			IT	IT	IT	IT	IT	IT	total	total	total	Icl	Icl	Icl	Icl	Icl
			IT	IT	IT	IT	IT	IT	total	total	total	Icl	Icl	Icl	Icl	Icl
Ensemble	Country	Gender	correction Coefficient 0.2 m/s (n.d.)	Correction Coefficient 0.4 m/s (n.d)	Correction Coefficient 1.0 m/s (n.d)	Correction Coefficient sitting (n.d)	Correction Coefficient walking (n.d)	correction walking+wind (n.d.)	im value 0.2 m/s (n.d)	im value 0.4 m/s (n.d)	im value 1 m/s (n.d)	correction Coefficient 0.2 m/s (n.d.)	Correction Coefficient 0.4 m/s (n.d)	Correction Coefficient 1.0 m/s (n.d)	Correction Coefficient sitting (n.d)	Correction Coefficient walking (n.d)
Measured/ Calculated			M	M	M	M	M	E	C	M	C	C	C	C	C	C
Nude		M	1.00	0.86	0.63	1.01	0.76	0.53								
ASTM	USA	M	1.00	0.88	0.67	0.90	0.70	0.52	0.28	0.29	0.32	1.00	0.90	0.69	0.82	0.66
C	Pakistan	M	1.00	0.85	0.62	0.95	0.65	0.48	0.35	0.36	0.40	1.00	0.85	0.61	0.92	0.59
E	India	M	1.00	0.86	0.61	0.85	0.61	0.46	0.35	0.36	0.39	1.00	0.87	0.60	0.78	0.54
I	Indonesia	M	1.00	0.86	0.62	0.95	0.71	0.50	0.35	0.36	0.40	1.00	0.86	0.60	0.90	0.67
J1	Kuwait	M	1.00	0.88	0.68				0.28	0.29	0.32	1.00	0.89	0.71		
J2	Kuwait	M	1.00	0.90	0.71	0.91	0.67	0.52	0.26	0.27	0.29	1.00	0.92	0.73	0.88	0.64
J3	Kuwait	M	1.00	0.88	0.68	0.82	0.63	0.49	0.30	0.31	0.34	1.00	0.89	0.70	0.78	0.60
K1	Kuwait	M	1.00	0.89	0.65	0.89	0.62	0.48	0.29	0.30	0.33	1.00	0.90	0.67	0.84	0.57
K2	Kuwait	M	1.00	0.87	0.68	0.87	0.58	0.48	0.30	0.32	0.34	1.00	0.87	0.70	0.83	0.53
K3	Kuwait	M	1.00	0.87	0.67	0.84	0.59	0.47	0.34	0.35	0.38	1.00	0.87	0.68	0.79	0.54
P	Nigeria/Ghana	M	1.00	0.86	0.60	0.93	0.71	0.50	0.28	0.29	0.32	1.00	0.86	0.58	0.87	0.68
Q	Nigeria/Ghana	M	1.00	0.84	0.59	0.93	0.69	0.49	0.31	0.32	0.35	1.00	0.83	0.56	0.87	0.64
R	Nigeria/Ghana	M	1.00	0.85	0.60	0.85	0.56	0.44	0.42	0.44	0.48	1.00	0.85	0.60	0.82	0.52
T	Nigeria/Ghana	M	1.00	0.83	0.58	0.93	0.69	0.48	0.54	0.56	0.61	1.00	0.80	0.51	0.83	0.61
U	Nigeria/Ghana	M	1.00	0.86	0.61	0.91	0.68	0.49	0.39	0.40	0.44	1.00	0.86	0.60	0.86	0.63
V1	Pakistan	M	1.00	0.84	0.58	0.94	0.66	0.47	0.34	0.35	0.39	1.00	0.84	0.55	0.90	0.61
V2	Pakistan	M	1.00	0.88	0.62	0.91	0.70	0.50	0.31	0.32	0.35	1.00	0.89	0.61	0.87	0.68
V3	Pakistan	M	1.00	0.93	0.66	0.89	0.68	0.50	0.27	0.28	0.31	1.00	0.96	0.67	0.84	0.65
Z	India	M	1.00	0.86	0.66	0.94	0.75	0.54	0.32	0.33	0.36	1.00	0.87	0.69	0.88	0.75
mean	(nude excluded)	M	1.000	0.868	0.636	0.901	0.661	0.489	0.331	0.343	0.374	1.000	0.871	0.634	0.848	0.617
sd	(nude excluded)	M	0.000	0.023	0.040	0.040	0.052	0.023	0.065	0.068	0.074	0.000	0.035	0.062	0.041	0.062

Table 7; Regional total Insulation (I_T) values. Average of static values measured with Victoria and Tore. All at 0.2 m.s^{-1}. Female Ensembles

Ensemble	Country	Gender	Wind speed	Head mean	Upper arms mean	Forearms mean	Hands mean	Chest mean	Abdomen mean	Back mean	Buttocks mean	Upper legs mean	Lower legs mean	Feet mean
Nude	LBORO	F	0.2	0.114	0.107	0.094	0.076	0.110	0.098	0.128	0.138	0.103	0.080	0.093
Nude	Lund	F	0.2	0.096	0.113	0.106	0.100	0.107	0.095	0.094	0.069	0.093	0.080	0.103
Nude	mean	F	0.2	0.105	0.110	0.100	0.088	0.108	0.097	0.111	0.104	0.098	0.080	0.098
A1	Pakistan	F	0.2	0.102	0.204	0.175	0.097	0.248	0.364	0.229	0.343	0.246	0.148	0.152
A2	India	F	0.2	0.105	0.222	0.187	0.095	0.274	0.336	0.357	0.422	0.267	0.159	0.155
ASTM		F	0.2	0.104	0.271	0.200	0.105	0.299	0.458	0.293	0.358	0.251	0.171	0.289
B1	India	F	0.2	0.104	0.171	0.106	0.099	0.234	0.416	0.215	0.330	0.242	0.138	0.164
B2	India	F	0.2	0.106	0.186	0.115	0.099	0.268	0.411	0.314	0.397	0.242	0.139	0.168
D1	Pakistan	F	0.2	0.104	0.179	0.125	0.096	0.241	0.343	0.203	0.321	0.239	0.136	0.159
D2	Pakistan	F	0.2	0.104	0.186	0.126	0.091	0.252	0.356	0.294	0.381	0.232	0.135	0.157
F1	Pakistan	F	0.2	0.148	0.436	0.282	0.112	0.432	0.586	0.479	0.465	0.274	0.208	0.302
F2	Pakistan	F	0.2	0.202	0.329	0.248	0.116	0.419	0.538	0.454	0.396	0.258	0.211	0.292
F3	Pakistan	F	0.2	0.222	0.378	0.255	0.115	0.471	0.574	0.494	0.417	0.255	0.216	0.301
F4	Pakistan	F	0.2	0.237	0.332	0.218	0.107	0.416	0.398	0.374	0.384	0.276	0.215	0.308
F5	Pakistan	F	0.2	0.145	0.304	0.267	0.120	0.390	0.571	0.408	0.404	0.264	0.209	0.296
F6	Pakistan	F	0.2	0.184	0.320	0.266	0.123	0.436	0.579	0.416	0.433	0.271	0.214	0.303
G1	Indonesia	F	0.2	0.106	0.306	0.305	0.124	0.371	0.621	0.313	0.321	0.200	0.159	0.273
G2	Indonesia	F	0.2	0.193	0.305	0.276	0.114	0.390	0.597	0.371	0.321	0.193	0.158	0.274
G3	Indonesia	F	0.2	0.190	0.213	0.196	0.108	0.264	0.317	0.264	0.225	0.164	0.155	0.302
H1	Indonesia	F	0.2	0.103	0.231	0.209	0.116	0.233	0.301	0.219	0.282	0.257	0.146	0.279
H2	Indonesia	F	0.2	0.200	0.234	0.203	0.113	0.278	0.307	0.265	0.262	0.251	0.151	0.273
L1	Kuwait	F	0.2	0.232	0.222	0.126	0.089	0.263	0.251	0.262	0.243	0.206	0.172	0.286
L2	Kuwait	F	0.2	0.229	0.234	0.152	0.098	0.319	0.343	0.328	0.273	0.180	0.168	0.278
L3	Kuwait	F	0.2	0.227	0.401	0.346	0.144	0.480	0.698	0.463	0.465	0.291	0.169	0.273
M-S1	Kuwait	F	0.2	0.102	0.334	0.250	0.141	0.308	0.413	0.312	0.346	0.291	0.166	0.202
M-S2	Kuwait	F	0.2	0.237	0.360	0.279	0.142	0.370	0.414	0.394	0.352	0.306	0.151	0.203
M-W1	Kuwait	F	0.2	0.101	0.406	0.330	0.132	0.367	0.622	0.359	0.410	0.350	0.203	0.308
M-W2	Kuwait	F	0.2	0.227	0.416	0.321	0.126	0.424	0.615	0.445	0.421	0.359	0.207	0.313
N	Nigeria/Ghana	F	0.2	0.129	0.245	0.113	0.097	0.222	0.227	0.209	0.233	0.196	0.124	0.163
O	Nigeria/Ghana	F	0.2	0.105	0.267	0.134	0.098	0.260	0.331	0.230	0.336	0.276	0.152	0.162
S	Nigeria/Ghana	F	0.2	0.105	0.269	0.174	0.100	0.228	0.311	0.227	0.333	0.240	0.154	0.156
W	China	F	0.2	0.096	0.120	0.094	0.090	0.210	0.205	0.191	0.233	0.192	0.129	0.215
X1	India	F	0.2	0.103	0.127	0.102	0.100	0.239	0.240	0.242	0.262	0.220	0.149	0.225
X2	India	F	0.2	0.149	0.203	0.105	0.090	0.283	0.353	0.355	0.360	0.248	0.154	0.264
Y1	India	F	0.2	0.105	0.173	0.103	0.095	0.272	0.477	0.198	0.302	0.314	0.145	0.160
Y2	India	F	0.2	0.159	0.246	0.097	0.093	0.368	0.677	0.405	0.404	0.363	0.178	0.281

Table 8; Regional total Insulation (I_T) values. Average of static values measured with Newton and Tore. All at 0.2 m.s^{-1}. Male Ensembles.

Ensemble	Country	Gender	Wind speed	Head mean	Upper arms mean	Forearms mean	Hands mean	Chest mean	Abdomen mean	Back mean	Buttocks mean	Upper legs mean	Lower legs mean	Feet mean
Nude	Lboro	M	0.2	0.119	0.104	0.094	0.072	0.113	0.112	0.117	0.131	0.091	0.081	0.083
Nude	Lund	M	0.2	0.096	0.113	0.106	0.100	0.107	0.095	0.094	0.069	0.093	0.080	0.103
Nude	mean	M	0.2	0.108	0.109	0.100	0.086	0.110	0.104	0.105	0.100	0.092	0.080	0.093
ASTM		M	0.2	0.099	0.240	0.190	0.085	0.282	0.430	0.275	0.440	0.242	0.166	0.241
C	Pakistan	M	0.2	0.099	0.231	0.208	0.092	0.207	0.367	0.215	0.372	0.315	0.167	0.219
E	India	M	0.2	0.104	0.220	0.221	0.098	0.199	0.399	0.198	0.463	0.375	0.196	0.237
I	Indonesia	M	0.2	0.103	0.196	0.094	0.084	0.227	0.362	0.202	0.416	0.213	0.145	0.233
J1	Kuwait	M	0.2	0.111	0.258	0.268	0.101	0.270	0.452	0.283	0.421	0.334	0.204	0.238
J2	Kuwait	M	0.2	0.182	0.269	0.258	0.099	0.333	0.462	0.354	0.437	0.341	0.206	0.239
J3	Kuwait	M	0.2	0.180	0.369	0.348	0.101	0.494	0.711	0.573	0.575	0.431	0.210	0.240
K1	Kuwait	M	0.2	0.102	0.239	0.230	0.107	0.277	0.474	0.278	0.449	0.363	0.176	0.192
K2	Kuwait	M	0.2	0.183	0.255	0.236	0.103	0.333	0.481	0.359	0.484	0.379	0.175	0.198
K3	Kuwait	M	0.2	0.178	0.360	0.328	0.114	0.452	0.688	0.541	0.647	0.472	0.183	0.194
P	Nigeria/Ghana	M	0.2	0.100	0.233	0.164	0.091	0.207	0.375	0.221	0.293	0.226	0.152	0.154
Q	Nigeria/Ghana	M	0.2	0.099	0.228	0.099	0.086	0.211	0.384	0.233	0.339	0.231	0.152	0.152
R	Nigeria/Ghana	M	0.2	0.117	0.433	0.321	0.144	0.319	0.617	0.339	0.505	0.364	0.201	0.171
T	Nigeria/Ghana	M	0.2	0.101	0.235	0.155	0.087	0.197	0.340	0.218	0.405	0.159	0.074	0.139
U	Nigeria/Ghana	M	0.2	0.120	0.254	0.112	0.085	0.228	0.411	0.208	0.333	0.284	0.153	0.158
V1	Pakistan	M	0.2	0.101	0.233	0.202	0.097	0.211	0.470	0.203	0.482	0.327	0.167	0.233
V2	Pakistan	M	0.2	0.101	0.277	0.252	0.097	0.279	0.623	0.277	0.613	0.369	0.205	0.235
V3	Pakistan	M	0.2	0.087	0.382	0.361	0.119	0.406	0.928	0.420	0.654	0.459	0.208	0.235
Z	India	M	0.2	0.145	0.166	0.097	0.085	0.256	0.372	0.309	0.369	0.167	0.166	0.239

Table 9; Regional Insulation correction factors for air velocity effect on static local clothing insulation I_T. Female data based on Victoria testing. To obtain the insulation value for different air speeds, the static 0.2 m.s^{-1} value needs to be multiplied with the respective factor shown here.

Ensemble	Country	Gender	Wind speed m/s	Head	Upper arms	Forearms	Hands	Chest	Abdomen	Back	Buttocks	Upper legs	Lower legs	Feet
Nude	LBORO	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Nude	LBORO	F	0.4	0.771	0.755	0.823	0.752	0.784	0.814	0.793	0.825	0.880	0.895	0.762
Nude	LBORO	F	1	0.527	0.540	0.594	0.513	0.571	0.619	0.564	0.586	0.648	0.664	0.533
A1	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
A1	Pakistan	F	0.4	0.819	0.863	0.892	0.815	0.860	0.829	0.907	0.936	0.890	0.927	0.859
A1	Pakistan	F	1.0	0.566	0.630	0.675	0.580	0.627	0.567	0.738	0.751	0.718	0.783	0.631
A2	India	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
A2	India	F	0.4	0.822	0.802	0.853	0.823	0.853	0.842	0.910	0.934	0.895	0.904	0.841
A2	India	F	1.0	0.580	0.572	0.632	0.589	0.608	0.625	0.679	0.622	0.714	0.745	0.635
ASTM	USA	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ASTM	USA	F	0.4	0.777	0.893	0.859	0.807	0.873	0.866	0.887	0.929	0.905	0.953	0.997
ASTM	USA	F	1.0	0.543	0.682	0.698	0.607	0.641	0.631	0.689	0.729	0.777	0.860	0.750
B1	India	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
B1	India	F	0.4	0.860	0.817	0.880	0.810	0.904	0.621	1.208	1.087	0.880	0.839	0.905
B1	India	F	1.0	0.589	0.539	0.643	0.574	0.548	0.385	0.587	0.718	0.602	0.599	0.676
B2	India	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
B2	India	F	0.4	0.813	0.772	0.832	0.813	0.761	0.646	0.846	0.895	0.844	0.831	0.896
B2	India	F	1.0	0.561	0.515	0.598	0.577	0.480	0.393	0.462	0.569	0.578	0.591	0.667
D1	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
D1	Pakistan	F	0.4	0.794	0.751	0.736	1.005	0.834	0.786	0.954	0.945	0.873	0.861	0.856
D1	Pakistan	F	1.0	0.573	0.500	0.536	0.664	0.558	0.515	0.652	0.722	0.611	0.673	0.669
D2	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
D2	Pakistan	F	0.4	0.857	0.807	0.808	0.971	0.899	0.731	0.887	0.867	0.957	0.927	0.947
D2	Pakistan	F	1.0	0.609	0.499	0.603	0.657	0.622	0.498	0.662	0.603	0.700	0.705	0.715
F1	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
F1	Pakistan	F	0.4	0.943	0.787	0.781	0.882	0.799	0.832	0.860	0.820	0.865	0.889	0.926
F1	Pakistan	F	1.0	0.497	0.588	0.553	0.545	0.542	0.458	0.542	0.705	0.738	0.828	0.719
F2	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
F2	Pakistan	F	0.4	0.761	0.857	0.839	0.815	0.829	0.830	0.883	0.893	0.903	0.915	0.993
F2	Pakistan	F	1.0	0.466	0.689	0.583	0.521	0.551	0.451	0.601	0.877	0.824	0.854	0.811
F3	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Ensemble	Country	Gender	Wind speed m/s	Head	Upper arms	Forearms	Hands	Chest	Abdomen	Back	Buttocks	Upper legs	Lower legs	Feet
F3	Pakistan	F	0.4	0.756	0.823	0.833	0.807	0.810	0.831	0.875	0.932	0.927	0.912	0.945
F3	Pakistan	F	1.0	0.469	0.601	0.592	0.589	0.561	0.573	0.517	0.693	0.747	0.813	0.762
F4	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
F4	Pakistan	F	0.4	0.744	0.924	0.974	0.863	0.934	1.152	1.160	0.984	0.875	0.881	0.902
F4	Pakistan	F	1.0	0.515	0.592	0.546	0.593	0.549	0.536	0.633	0.714	0.750	0.828	0.714
F5	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
F5	Pakistan	F	0.4	0.805	0.864	0.831	0.897	0.833	0.787	0.922	0.909	0.895	0.930	0.966
F5	Pakistan	F	1.0	0.520	0.628	0.581	0.652	0.612	0.534	0.561	0.638	0.712	0.875	0.746
F6	Pakistan	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
F6	Pakistan	F	0.4	0.771	0.825	0.821	0.908	0.801	0.790	0.868	0.856	0.900	0.979	0.943
F6	Pakistan	F	1.0	0.517	0.634	0.564	0.652	0.576	0.543	0.531	0.627	0.719	0.864	0.767
G1	Indonesia	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
G1	Indonesia	F	0.4	0.788	0.902	0.881	0.831	0.809	0.745	0.906	0.909	0.877	0.931	0.921
G1	Indonesia	F	1.0	0.564	0.802	0.754	0.604	0.553	0.521	0.729	0.733	0.697	0.812	0.761
G2	Indonesia	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
G2	Indonesia	F	0.4	0.784	0.940	0.887	0.830	0.838	0.739	0.918	0.912	0.879	0.960	0.884
G2	Indonesia	F	1.0	0.505	0.809	0.722	0.614	0.585	0.524	0.724	0.704	0.666	0.830	0.711
G3	Indonesia	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
G3	Indonesia	F	0.4	0.746	0.872	0.931	0.827	0.802	0.854	0.859	0.882	0.894	0.979	0.916
G3	Indonesia	F	1.0	0.468	0.694	0.836	0.639	0.600	0.702	0.677	0.715	0.702	0.808	0.726
H1	Indonesia	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
H1	Indonesia	F	0.4	0.822	0.914	0.899	0.809	0.866	0.812	0.881	0.917	0.940	0.949	0.860
H1	Indonesia	F	1.0	0.578	0.739	0.784	0.591	0.648	0.616	0.734	0.807	0.792	0.904	0.671
H2	Indonesia	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
H2	Indonesia	F	0.4	0.820	0.897	0.865	0.788	0.847	0.845	0.881	0.916	0.928	0.891	0.859
H2	Indonesia	F	1.0	0.542	0.724	0.724	0.573	0.623	0.593	0.746	0.773	0.795	0.864	0.670
L1	Kuwait	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L1	Kuwait	F	0.4	0.838	0.791	0.842	0.812	0.772	0.853	0.846	0.914	0.914	0.937	0.893
L1	Kuwait	F	1.0	0.615	0.503	0.602	0.587	0.516	0.613	0.573	0.713	0.787	0.839	0.708
L2	Kuwait	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L2	Kuwait	F	0.4	0.837	0.830	0.873	0.844	0.808	0.841	0.860	0.895	0.888	0.942	0.871
L2	Kuwait	F	1.0	0.601	0.605	0.706	0.631	0.608	0.657	0.632	0.700	0.786	0.859	0.687
L3	Kuwait	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L3	Kuwait	F	0.4	0.832	0.912	0.928	0.740	0.818	0.774	0.931	0.893	0.870	0.948	0.886
L3	Kuwait	F	1.0	0.607	0.809	0.837	0.546	0.589	0.573	0.852	0.779	0.754	0.847	0.677
M-S1	Kuwait	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Ensemble	Country	Gender	Wind speed m/s	Head	Upper arms	Forearms	Hands	Chest	Abdomen	Back	Buttocks	Upper legs	Lower legs	Feet
M-S1	Kuwait	F	0.4	0.817	0.896	0.826	0.883	0.856	0.825	0.946	0.942	0.912	0.893	0.843
M-S1	Kuwait	F	1.0	0.588	0.598	0.556	0.624	0.622	0.472	0.799	0.865	0.757	0.747	0.610
M-S2	Kuwait	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
M-S2	Kuwait	F	0.4	0.764	0.878	0.811	0.854	0.852	0.809	0.973	0.936	0.891	0.945	0.843
M-S2	Kuwait	F	1.0	0.483	0.585	0.519	0.604	0.581	0.474	0.715	0.827	0.743	0.790	0.607
M-W1	Kuwait	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
M-W1	Kuwait	F	0.4	0.820	0.848	0.817	0.790	0.884	0.853	0.937	0.932	0.919	0.918	0.915
M-W1	Kuwait	F	1.0	0.575	0.603	0.568	0.566	0.703	0.560	0.753	0.770	0.773	0.814	0.696
M-W2	Kuwait	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
M-W2	Kuwait	F	0.4	0.787	0.905	0.799	0.756	0.857	0.813	0.952	0.955	0.947	0.954	0.887
M-W2	Kuwait	F	1.0	0.516	0.719	0.589	0.543	0.598	0.525	0.796	0.857	0.779	0.817	0.698
N	Nigeria/Ghana	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
N	Nigeria/Ghana	F	0.4	0.837	0.878	0.821	0.813	0.881	0.889	0.880	0.895	0.904	0.887	0.796
N	Nigeria/Ghana	F	1.0	0.587	0.610	0.578	0.550	0.660	0.695	0.647	0.709	0.748	0.812	0.595
O	Nigeria/Ghana	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
O	Nigeria/Ghana	F	0.4	0.812	0.782	0.800	0.716	0.801	0.827	0.900	1.008	0.906	0.921	0.872
O	Nigeria/Ghana	F	1.0	0.603	0.568	0.645	0.557	0.547	0.627	0.678	0.868	0.702	0.760	0.660
S	Nigeria/Ghana	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
S	Nigeria/Ghana	F	0.4	0.821	0.732	0.910	0.798	0.739	0.725	0.814	0.874	0.860	0.904	0.829
S	Nigeria/Ghana	F	1.0	0.588	0.501	0.660	0.552	0.504	0.530	0.593	0.703	0.615	0.690	0.605
W	China	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
W	China	F	0.4	1.049	1.418	0.966	0.895	1.200	1.353	1.078	0.975	0.940	0.665	0.413
W	China	F	1.0	0.736	1.067	0.743	0.642	0.949	1.129	0.916	0.837	0.726	0.575	0.311
X1	India	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
X1	India	F	0.4	0.809	0.763	0.829	0.722	0.810	0.843	0.857	0.900	0.842	0.959	0.911
X1	India	F	1.0	0.566	0.546	0.622	0.507	0.584	0.631	0.672	0.728	0.633	0.763	0.737
X2	India	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
X2	India	F	0.4	0.826	0.854	0.853	0.771	0.878	0.771	0.914	0.916	0.855	0.950	0.908
X2	India	F	1.0	0.603	0.669	0.605	0.563	0.712	0.527	0.787	0.737	0.642	0.778	0.739
Y1	India	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Y1	India	F	0.4	0.852	0.820	0.863	0.771	0.809	0.787	0.859	0.903	0.874	0.898	0.839
Y1	India	F	1.0	0.610	0.628	0.635	0.568	0.588	0.493	0.661	0.703	0.659	0.706	0.632
Y2	India	F	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Y2	India	F	0.4	0.833	0.881	0.891	0.763	0.882	0.792	0.899	0.909	0.924	0.965	0.880
Y2	India	F	1.0	0.616	0.703	0.655	0.558	0.738	0.495	0.738	0.740	0.744	0.843	0.739

Table 10; Regional Insulation correction factors for air velocity effect on static local clothing insulation I_T. To obtain the insulation value for different air speeds, the static 0.2 $m.s^{-1}$ value needs to be multiplied with the respective factor shown here. Male data based on Newton testing.

Ensemble	Country	Gender	Wind speed m/s	Head	Upper arms	Forearms	Hands	Chest	Abdomen	Back	Buttocks	Upper legs	Lower legs	Feet
Nude	LBORO	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Nude	LBORO	M	0.4	0.848	0.832	0.854	0.809	0.819	0.761	0.974	0.881	0.918	0.846	0.838
Nude	LBORO	M	1.0	0.561	0.587	0.603	0.566	0.602	0.553	0.727	0.551	0.721	0.654	0.623
ASTM	USA	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ASTM	USA	M	0.4	0.811	0.889	0.888	0.784	0.859	0.874	0.957	0.909	0.946	0.961	0.944
ASTM	USA	M	1.0	0.479	0.709	0.695	0.518	0.648	0.667	0.812	0.757	0.796	0.888	0.854
C	Pakistan	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
C	Pakistan	M	0.4	0.801	0.840	0.833	0.773	0.770	0.741	0.935	0.895	0.899	0.964	0.948
C	Pakistan	M	1.0	0.442	0.608	0.654	0.512	0.476	0.577	0.792	0.863	0.757	0.855	0.854
E	India	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
E	India	M	0.4	0.771	0.856	0.761	0.757	0.838	0.837	0.934	0.927	0.994	1.033	0.953
E	India	M	1.0	0.412	0.600	0.513	0.471	0.594	0.644	0.726	0.818	0.808	1.043	0.835
I	Indonesia	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
I	Indonesia	M	0.4	0.806	0.857	0.786	0.778	0.805	0.749	0.923	0.835	0.950	0.967	0.955
I	Indonesia	M	1.0	0.478	0.570	0.554	0.528	0.551	0.490	0.673	0.619	0.767	0.871	0.861
J1	Kuwait	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
J1	Kuwait	M	0.4	0.796	0.869	0.854	0.838	0.843	0.832	0.940	0.928	0.965	0.961	0.915
J1	Kuwait	M	1.0	0.443	0.702	0.700	0.576	0.677	0.635	0.821	0.832	0.822	0.990	0.813
J2	Kuwait	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
J2	Kuwait	M	0.4	0.782	0.888	0.865	0.855	0.824	0.831	0.962	0.956	0.966	1.019	0.943
J2	Kuwait	M	1.0	0.445	0.727	0.723	0.588	0.624	0.662	0.846	0.910	0.816	0.990	0.848
J3	Kuwait	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
J3	Kuwait	M	0.4	0.810	0.909	0.903	0.791	0.880	0.810	0.991	0.946	0.932	0.939	0.939
J3	Kuwait	M	1.0	0.473	0.756	0.760	0.517	0.622	0.527	0.881	0.930	0.757	1.003	0.848
K1	Kuwait	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
K1	Kuwait	M	0.4	0.803	0.895	0.833	0.757	0.883	0.809	0.977	0.947	0.997	1.020	0.927
K1	Kuwait	M	1.0	0.428	0.707	0.632	0.478	0.658	0.607	0.851	0.833	0.868	1.103	0.825
K2	Kuwait	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
K2	Kuwait	M	0.4	0.762	0.848	0.836	0.767	0.829	0.820	0.977	0.943	0.972	0.964	0.931
K2	Kuwait	M	1.0	0.396	0.718	0.654	0.503	0.623	0.663	0.781	0.895	0.849	1.130	0.827
K3	Kuwait	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
K3	Kuwait	M	0.4	0.795	0.919	0.907	0.762	0.872	0.833	0.947	0.924	0.910	0.923	0.928

Ensemble	Country	Gender	Wind speed m/s	Head	Upper arms	Forearms	Hands	Chest	Abdomen	Back	Buttocks	Upper legs	Lower legs	Feet
K3	Kuwait	M	1.0	0.432	0.738	0.754	0.496	0.595	0.471	0.777	0.809	0.755	1.092	0.822
P	Nigeria/Ghana	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P	Nigeria/Ghana	M	0.4	0.814	0.807	1.023	0.669	0.731	0.720	0.856	0.933	0.956	1.013	0.929
P	Nigeria/Ghana	M	1.0	0.478	0.578	0.760	0.433	0.473	0.473	0.570	0.748	0.738	0.871	0.720
Q	Nigeria/Ghana	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Q	Nigeria/Ghana	M	0.4	0.808	0.777	0.778	0.787	0.728	0.767	0.908	0.903	0.916	0.986	0.921
Q	Nigeria/Ghana	M	1.0	0.472	0.527	0.524	0.526	0.485	0.533	0.682	0.761	0.694	0.853	0.718
R	Nigeria/Ghana	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
R	Nigeria/Ghana	M	0.4	0.827	0.864	0.732	0.737	0.867	0.869	0.930	0.789	0.895	0.964	0.871
R	Nigeria/Ghana	M	1.0	0.542	0.687	0.557	0.422	0.562	0.527	0.794	0.927	0.715	0.766	0.621
T	Nigeria/Ghana	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
T	Nigeria/Ghana	M	0.4	0.815	0.887	0.877	0.783	0.747	0.752	0.913	0.846	0.836	0.849	0.862
T	Nigeria/Ghana	M	1.0	0.478	0.648	0.640	0.519	0.489	0.488	0.679	0.619	0.581	0.637	0.621
U	Nigeria/Ghana	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U	Nigeria/Ghana	M	0.4	0.829	0.842	0.772	0.782	0.775	0.783	0.943	0.921	0.916	0.990	0.907
U	Nigeria/Ghana	M	1.0	0.553	0.580	0.521	0.513	0.464	0.541	0.756	0.782	0.782	0.835	0.688
V1	Pakistan	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
V1	Pakistan	M	0.4	0.795	0.846	0.861	0.708	0.791	0.741	0.989	1.041	0.870	0.919	0.916
V1	Pakistan	M	1.0	0.444	0.598	0.607	0.455	0.499	0.444	0.745	0.768	0.642	0.782	0.812
V2	Pakistan	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
V2	Pakistan	M	0.4	0.804	0.862	0.853	0.804	0.881	0.846	0.900	0.928	0.935	0.980	0.958
V2	Pakistan	M	1.0	0.460	0.684	0.662	0.455	0.593	0.475	0.838	0.763	0.682	0.876	0.840
V3	Pakistan	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
V3	Pakistan	M	0.4	1.000	0.911	0.889	0.829	0.904	0.782	0.933	0.928	0.889	0.956	0.950
V3	Pakistan	M	1.0	0.630	0.795	0.786	0.452	0.548	0.329	0.890	0.745	0.575	0.870	0.839
Z	India	M	0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Z	India	M	0.4	0.802	0.846	0.794	0.788	0.864	0.881	0.870	0.911	0.915	0.954	0.941
Z	India	M	1.0	0.539	0.618	0.553	0.526	0.691	0.734	0.711	0.773	0.768	0.865	0.859

Table 11, Regional Insulation correction factors for sitting effect on static local clothing insulation I_T. Data based on Tore testing. To obtain the insulation value for sitting, the static 0.2 $m.s^{-1}$ value needs to be multiplied with the respective factor shown here.

Ensemble	Country	Gender	Head	Upper arm	Forearm	Hand	Chest	Abdomen	Back	Buttocks	Thigh	Calf	Foot
Air layer			0.958	0.938	0.952	0.908	1.054	1.064	0.945	0.888	1.117	1.059	1.008
ASTM ref. calibr. ens.			0.961	0.794	0.813	0.863	1.129	1.232	0.910	0.596	0.749	1.069	1.025
A1	Pakistan	Female	0.976	0.891	0.753	0.820	1.002	1.328	0.908	0.620	0.982	1.117	1.052
A2	Pakistan	Female	0.964	0.818	0.694	0.868	1.111	1.556	0.741	0.535	0.909	1.026	1.031
B1	India	Female	0.972	0.860	0.842	0.872	1.048	1.221	0.840	0.648	1.113	1.146	1.047
C	Pakistan	Male	0.995	0.778	0.835	0.880	1.206	1.584	0.930	0.513	0.906	1.086	1.047
D1	Pakistan	Female	0.992	0.841	0.850	0.837	1.048	1.354	0.887	0.652	1.247	1.148	1.021
E	India	Male	0.931	0.673	0.643	0.765	1.019	1.977	0.932	0.490	0.842	0.920	0.957
F1	Pakistan	Female	1.150	0.758	0.644	0.833	1.218	1.716	0.819	0.521	0.966	1.051	1.059
F2	Pakistan	Female	0.999	0.863	0.826	0.893	1.267	1.442	0.842	0.510	0.987	1.114	0.951
F3	Pakistan	Female	0.963	0.735	0.666	0.854	0.997	1.224	0.719	0.505	1.087	0.968	1.002
F4	Pakistan	Female	1.106	0.800	0.632	0.883	0.866	1.434	0.764	0.490	0.935	1.198	1.051
F5	Pakistan	Female	1.039	0.856	0.732	0.879	1.210	1.590	0.809	0.584	0.952	1.078	1.149
F6	Pakistan	Female	1.040	0.801	0.799	0.915	1.255	1.308	0.934	0.465	0.930	1.195	0.914
G1	Indonesia	Female	1.888	0.787	0.566	0.910	0.753	1.184	0.842	0.629	1.606	1.119	0.682
G2	Indonesia	Female	1.030	0.747	0.774	0.857	1.144	1.132	0.758	0.658	1.025	1.041	1.079
G3	Indonesia	Female	0.955	0.983	0.940	0.896	1.154	1.334	0.874	0.644	0.981	1.111	0.824
H2	Indonesia	Female	1.003	0.791	0.878	0.858	1.116	1.599	0.826	0.671	0.895	1.111	0.967
I	Indonesia	Male	0.969	0.973	0.923	0.892	1.062	1.391	0.943	0.559	0.904	1.073	0.999
J2	Kuwait	Male	0.996	0.774	0.811	0.796	1.079	1.424	0.816	0.542	0.850	1.203	1.060
J3	Kuwait	Male	0.964	0.716	0.746	0.720	1.173	1.226	0.606	0.445	0.711	1.022	0.992
K1	Kuwait	Male	0.957	0.786	0.650	0.828	1.097	1.298	0.825	0.458	0.927	1.081	0.905
K2	Kuwait	Male	1.001	0.778	0.637	0.857	1.116	1.506	0.785	0.467	0.829	1.053	0.922
K3	Kuwait	Male	0.997	0.756	0.756	0.630	1.331	1.626	0.678	0.394	0.790	1.025	0.876
L1	Kuwait	Female	0.980	0.771	0.738	0.906	1.041	1.578	0.806	0.765	0.810	0.993	0.919
L2	Kuwait	Female	0.918	0.858	0.748	0.893	1.075	1.457	0.826	0.726	0.961	0.968	0.970
M-S2	Kuwait	Female	0.993	0.618	0.515	0.692	1.195	1.177	0.782	0.678	1.025	1.254	1.165
M-W2	Kuwait	Female	0.875	0.660	0.646	0.709	1.098	1.378	0.761	0.581	0.917	1.195	1.088
N	Nigeria/Ghana	female	1.016	0.752	0.811	0.885	1.149	1.161	0.880	0.614	1.082	1.049	0.926
O	Nigeria/Ghana	Female	0.980	0.802	0.801	0.870	1.022	1.865	0.829	0.582	1.087	1.070	0.888
P	Nigeria/Gh	Male	1.002	0.821	0.586	0.882	1.020	1.227	0.940	0.710	0.882	1.157	1.058

Ensemble	Country	Gender	Head	Upper arm	Forearm	Hand	Chest	Abdomen	Back	Buttocks	Thigh	Calf	Foot
	ana												
Q	Nigeria/Ghana	Male	1.009	0.763	0.927	0.869	1.061	1.260	0.903	0.636	0.837	1.172	1.057
R	Nigeria/Ghana	Male	0.976	0.622	0.604	0.562	1.157	1.213	0.801	0.464	0.887	1.097	1.014
S	Nigeria/Ghana	Female	0.967	0.740	0.742	0.831	1.067	1.393	0.927	0.624	1.023	1.009	1.061
T	Nigeria/Ghana	Male	1.001	0.732	0.716	0.841	1.093	1.292	0.894	0.566	0.910	1.083	0.997
U	Nigeria/Ghana	Male	0.958	0.807	0.803	0.917	1.082	1.193	0.914	0.571	0.791	1.182	0.962
V1	Pakistan	Male	0.985	0.781	0.777	0.842	1.081	1.566	0.927	0.486	0.996	1.068	1.041
V2	Pakistan	Male	0.993	0.732	0.706	0.891	1.102	1.636	0.846	0.444	0.911	1.075	1.015
V3	Pakistan	Male	0.995	0.755	0.778	0.733	1.246	1.581	0.765	0.483	0.820	0.999	1.020
W	China	Female	0.955	0.842	1.172	0.769	1.005	1.681	1.071	0.698	1.013	0.852	1.014
X1	India	Female	1.001	0.831	0.847	0.859	1.016	1.301	0.858	0.621	0.937	1.069	1.014
X2	India	Female	1.008	0.832	0.836	0.854	1.348	1.369	0.830	0.598	0.789	1.017	1.125
Y1	India	Female	0.971	0.738	0.875	0.860	0.985	1.398	0.879	0.636	1.145	1.063	0.971
Y2	India	Female	1.004	0.801	0.941	0.867	1.054	1.377	0.813	0.640	0.916	0.929	0.913
Z	India	Male	0.915	0.896	0.912	0.940	1.029	1.329	0.771	0.722	0.974	0.982	1.008
		Mean	1.007	0.792	0.774	0.840	1.097	1.404	0.843	0.585	0.954	1.073	0.997
		SD	0.141	0.077	0.124	0.078	0.109	0.198	0.083	0.100	0.149	0.082	0.086

Table 12, Regional Insulation correction factors for walking effect on local clothing insulation I_T. To obtain the insulation value for walking, the static 0.2 $m.s^{-1}$ value needs to be multiplied with the respective factor shown here. Data based on Tore testing. [NOTE: walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward; an estimate of the combined effect for the whole body is provided in earlier tables based on data by Havenith & Nilsson, 2004. Due to lack of data this is not possible for the local data].

Ensemble	Country	Gender	Head	Upper arm	Forearm	Hand	Chest	Abdomen	Back	Buttocks	Thigh	Calf	Foot
Air layer			0.970	0.754	0.542	0.545	0.969	0.850	0.955	0.913	0.822	0.664	0.531
ASHRAE ref. calibr. ens.			0.970	0.647	0.677	0.536	0.917	0.795	0.940	0.774	0.513	0.669	0.817
A1	Pakistan	Female	1.003	0.696	0.523	0.496	0.838	0.642	0.819	0.703	0.586	0.665	0.636
A2	Pakistan	Female	0.991	0.638	0.465	0.516	0.852	0.752	0.714	0.634	0.543	0.618	0.538
B1	India	Female	1.008	0.687	0.495	0.522	0.909	0.615	0.884	0.806	0.519	0.494	0.626
C	Pakistan	Male	0.999	0.550	0.528	0.516	0.858	0.765	0.738	0.619	0.513	0.547	0.848
D1	Pakistan	Female	0.968	0.551	0.475	0.508	0.883	0.749	0.889	0.741	0.589	0.608	0.618
E	India	Male	1.011	0.455	0.370	0.446	0.824	0.796	0.751	0.610	0.484	0.542	0.779
F1	Pakistan	Female	1.160	0.548	0.444	0.506	0.871	0.686	0.759	0.692	0.608	0.685	0.771
F2	Pakistan	Female	1.013	0.681	0.597	0.515	0.966	0.680	0.753	0.586	0.644	0.667	0.736
F3	Pakistan	Female	1.003	0.642	0.517	0.524	0.773	0.648	0.673	0.707	0.610	0.643	0.749
F4	Pakistan	Female	1.099	0.506	0.464	0.524	0.799	0.675	0.690	0.576	0.644	0.682	0.826
F5	Pakistan	Female	1.011	0.695	0.479	0.533	0.841	0.704	0.736	0.639	0.607	0.666	0.814
F6	Pakistan	Female	1.017	0.631	0.524	0.530	0.915	0.802	0.787	0.629	0.497	0.645	0.724
G1	Indonesia	Female	1.902	0.534	0.340	0.522	0.519	0.588	0.649	0.803	0.955	0.551	0.405
G2	Indonesia	Female	0.993	0.702	0.604	0.504	0.894	0.696	0.926	0.790	0.698	0.713	0.863
G3	Indonesia	Female	0.997	0.753	0.633	0.534	0.817	0.792	0.862	0.809	0.710	0.692	0.686
H2	Indonesia	Female	1.011	0.668	0.599	0.507	0.875	0.768	0.837	0.802	0.520	0.477	0.760
I	Indonesia	Male	0.984	0.620	0.545	0.548	0.850	0.743	0.889	0.779	0.639	0.752	0.810
J2	Kuwait	Male	0.965	0.687	0.614	0.471	0.801	0.712	0.800	0.709	0.540	0.626	0.806
J3	Kuwait	Male	0.983	0.675	0.641	0.416	0.751	0.637	0.673	0.632	0.468	0.618	0.820
K1	Kuwait	Male	0.990	0.579	0.396	0.436	0.847	0.600	0.866	0.595	0.516	0.577	0.566
K2	Kuwait	Male	1.011	0.603	0.380	0.457	0.844	0.609	0.778	0.620	0.481	0.537	0.525
K3	Kuwait	Male	1.022	0.596	0.505	0.380	0.924	0.675	0.782	0.714	0.468	0.509	0.567
L1	Kuwait	Female	1.020	0.634	0.432	0.555	0.916	0.860	0.902	0.830	0.729	0.818	0.806
L2	Kuwait	Female	1.029	0.740	0.544	0.544	0.984	0.795	0.907	0.884	0.921	0.833	0.806
M-S2	Kuwait	Female	1.004	0.394	0.308	0.411	0.831	0.529	0.702	0.539	0.478	0.459	0.519
M-W2	Kuwait	Female	0.953	0.527	0.437	0.399	0.804	0.667	0.824	0.742	0.543	0.572	0.708
N	Nigeria/Ghana	female	1.006	0.481	0.470	0.547	0.835	0.712	0.765	0.633	0.659	0.538	0.619
O	Nigeria/Ghana	Female	1.012	0.546	0.489	0.546	0.782	0.717	0.781	0.714	0.622	0.594	0.640
P	Nigeria/Ghana	Male	1.038	0.644	0.496	0.524	0.815	0.698	0.784	0.961	0.654	0.761	0.628

Ensemble	Country	Gender	Head	Upper arm	Forearm	Hand	Chest	Abdomen	Back	Buttocks	Thigh	Calf	Foot
Q	Nigeria/Ghana	Male	1.001	0.569	0.536	0.526	0.853	0.721	0.793	0.848	0.640	0.783	0.642
R	Nigeria/Ghana	Male	1.010	0.390	0.344	0.313	0.807	0.623	0.720	0.660	0.489	0.568	0.567
S	Nigeria/Ghana	Female	0.991	0.622	0.504	0.526	0.886	0.738	0.806	0.766	0.581	0.564	0.654
T	Nigeria/Ghana	Male	0.979	0.603	0.494	0.512	0.899	0.767	0.758	0.775	0.610	0.732	0.687
U	Nigeria/Ghana	Male	0.980	0.530	0.484	0.558	0.804	0.714	0.809	0.857	0.649	0.766	0.597
V1	Pakistan	Male	1.016	0.560	0.455	0.518	0.870	0.660	0.794	0.641	0.540	0.620	0.836
V2	Pakistan	Male	1.066	0.621	0.551	0.526	0.840	0.627	0.814	0.557	0.573	0.674	0.829
V3	Pakistan	Male	0.991	0.650	0.618	0.424	0.783	0.711	0.792	0.709	0.521	0.662	0.856
W	China	Female	0.907	0.683	0.723	0.479	0.916	0.759	1.064	0.832	0.506	0.488	0.640
X1	India	Female	1.007	0.663	0.512	0.527	0.948	0.790	0.899	0.885	0.644	0.750	0.672
X2	India	Female	1.021	0.612	0.504	0.535	0.963	0.771	0.930	0.813	0.594	0.778	0.906
Y1	India	Female	0.953	0.591	0.508	0.530	0.912	0.697	0.879	0.825	0.615	0.556	0.581
Y2	India	Female	0.983	0.601	0.538	0.551	0.841	0.700	0.814	0.827	0.511	0.483	0.740
Z	India	Male	0.988	0.628	0.562	0.581	0.890	0.917	0.861	0.906	0.870	0.727	0.824
		Mean	1.023	0.609	0.508	0.503	0.856	0.714	0.812	0.735	0.603	0.635	0.702
		SD	0.139	0.084	0.088	0.054	0.076	0.078	0.086	0.107	0.115	0.098	0.118

Conclusions

Four different manikins in three different laboratories, were used to determine the clothing insulation values of 52 clothing configurations. Male clothing was tested on the manikins Newton, Tore and Walter. Female ensembles were tested on the manikins Victoria, Tore and Walter. Using different manikins to replicate these tests resulted in a range of values for each ensemble. The manikin shape is considered to be the main factor in this variation with the female shape manikin (Victoria) providing slightly higher (8%) values than the other manikins. Also the local conditions in the different climatic chambers may have contributed to the variability. Having this variability is considered to be a better representation of the variability to be expected when these garments are worn in real life conditions, than if only a single manikin were used, given the expected variability in body shapes of wearers of the ensembles in real life. This was one of the reasons to use a multi-manikin approach.

Results indicate that substantial differences in insulation are observed for the different manikin shapes and sizes. These shapes interact with the clothing fit and drape and through this affect the air layers in and on the clothing.

Values observed for the vapor permeability index i_m for a static manikin in 0.2 $m.S^{-1}$ air velocity were on average 0.34 ± 0.05 (n.d.).

Fifty two configurations were tested for the effects of air velocity, forty three were tested for the effects of posture (sitting) and walking. The walking was measured in the same relative air speed as standing and sitting. Hence this only represents the effect of the pumping effect of the movement. It does NOT include the effect of the air speed generated by moving forward; an estimate of the combined effect is provided based on data by Havenith & Nilsson, 2004.

Corrections for air velocity and walking are stronger than those observed for western clothing in the past, most likely related to more open weave fabrics and loose fit designs. Similarly the relation of the clothing surface area factor to intrinsic clothing insulation was different from that published for western clothing. Using the new data for validation, the reliability of surface area prediction based on clothing insulation values was considered low, which however was also the case for those obtained in the past for western clothing. This seems to be overlooked, as its use is widespread. It has to be concluded that reliable f_{cl} values can only be obtained when these are actually measured. Having said this, the concept of the f_{cl} factor for the non-western clothing may not work in the first place, as the wide falling robes and gowns do not match the clothing and air layer model (Figure 11) on which the f_{cl} concept is based.

Though static insulation values were obtained from 3 labs, with repeated tests in each, the values for the corrections for wind, walking, sitting and the values for clothing vapor resistance were obtained in one lab each. The reason for this was the budget constraint, while trying to maximize the collected information. In the future it would be beneficial to validate some of these values for the same clothing in other labs.

The results provide an extensive database of non-western clothing styles in different wear configurations, in different air velocities, postures and movement. As such this is expected to be a valuable addition to ASHRAE 55 and ISO 7730 and ISO 9920.

Utilization

This research relates to AHSRAE Handbook – Fundamentals, 2013; Section 'INDOOR ENVIRONMENTAL QUALITY', Chapter 9. Thermal Comfort, to ASHRAE standard 55 and to ISO standards 7730 and 9920. The values for non-western clothing insulation presented in this report will assist in the use of these standards and allows engineers to determine comfort guidelines for buildings in countries where non-western dress is common. Values for insulation and for the effects of posture, movement and wind on insulation can be incorporated in the standards and in the Handbook.

Data obtained on the insulation of individual body parts can be used by CFD modelers to incorporate realistic insulation data in their models.

This new data on non-western clothing exceeds the level of detail available for existing data on western clothing (regional insulation data; wind posture and movement effects for individual ensembles). Hence, a need for a research project on collecting similar data on western clothing and thereby expanding the existing knowledge in that area could be identified.

Project Synopsis

With the expansion of building activities in the non-western world, a need to make thermal comfort standards for the assessment of buildings, ASHRAE standard 55, applicable to non-western circumstances was identified. This research project provides data for one of the essential input parameters for this standard: clothing insulation. The results provide an extensive database of insulation values of non-western clothing styles in different wear configurations, in different air velocities, postures and movement. As such this is expected to be a valuable addition to ASHRAE 55 and ISO 7730 and ISO 9920. In addition, data obtained on the insulation of individual body parts can be used by CFD modelers to incorporate realistic insulation data in their models.

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REFERENCES

Ahmad, S., Ibrahim, N., 2003. A study on thermal comfort in classrooms in Malaysia Proceedings of the 20th Conference on Passive and Low Energy Architecture, PLEA2003. Santiago, CHILE.

Al-Ajmi, F., Loveday, D., Bedwell, K., Havenith, G., 2008. Thermal insulation and clothing area factors of typical Arabian Gulf clothing ensembles for males and females: Measurements using thermal manikins. Applied Ergonomics 39 (3), 407-414.

Al-Rashidi, K., Loveday, D., Al-Mutawa, N., & Havenith, G., 2012. A comparison of methods for assessing the thermal insulation value of children's school wear in Kuwait. APPL ERGON, 43(1), 203-210. doi:10.1016/j.apergo.2011.05.010

Al-Rashidi, K.E., Loveday, D.L., Al-Mutawa, N.K., 2009a. Investigating the applicability of different thermal comfort models in Kuwait classrooms operated in hybrid air-conditioning mode in Proceedings of the International Conference on Sustainability in Energy and Buildings, SEB09. Brighton, UK. Part 6, 347-355, DOI: 10.1007/978-3-642-03454-1_36.

Al-Rashidi, K.E., Loveday, D.L., Al-Mutawa, N.K., 2009b. Investigating the applicability of different thermal comfort models in naturally ventilated classrooms in Kuwait in Proceedings of the Engineering Congress on Alternative Energy Applications, EC2009. Kuwait.

Al-Rashidi, K.E., Loveday, D.L., Al-Mutawa, N.K., 2010. Investigating the applicability of different thermal comfort models in air-conditioned classrooms in Kuwait in Proceedings of the 10th REHVA World Congress on Sustainable Energy Use in Buildings, Clima2010. Antalya, Turkey. ISBN: 978-975-6907-14-6.

ASHRAE 55, 2004. Thermal Environmental Conditions for Human Occupancy. ANSI/ASHRAE Standard 55-2004. American Society of Heating Refrigeration and Air-conditioning Engineers. ASHRAE Inc., Atlanta, USA.

ASHRAE, 2009. ASHRAE Handbook Fundamentals, Chapter 9, Thermal comfort. American Society of Heating Refrigeration and Air-conditioning Engineers. ASHRAE Inc., Atlanta, USA.

Cheong, K., Djunaedy, E., Chua, Y., Tham, K., Sekhar, S., Wong, N., Ullah, M., 2003. Thermal comfort study of an air-conditioned lecture theatre in the tropics. Building and Environment 38 (1), 63-73.

Fanger, P.O., 1972. Thermal Comfort: Analysis and Applications in Engineering. McGraw-Hill New York, USA.

Havenith, G., 2002.The interaction between clothing insulation and thermoregulation. Exogenous Dermatology 1 (5), 221-230.

Havenith, G., 2005. Clothing heat exchange models for research and application in Proceedings of the International Conference on Environmental Ergonomics. Ystad, Sweden.

Havenith, G., Fiala, D., Błazejczyk, K., Richards, M., Bröde, P., Holmér, I., Rintamaki H. Benshabat, Y. & Jendritzky, G. (2012). The UTCI-clothing model, Int J Biometeorol 56:461–470.

Havenith, G., Heus, R., Lotens, W.A. 1990b, “Clothing ventilation, vapour resistance and permeability index: changes due to posture, movement and wind.” Ergonomics 33/8, pp. 989-1005.

Havenith, G., Heus, R., Lotens, W.A., 1990a, “Resultant clothing insulation: a function of body movement, posture, wind, clothing fit and ensemble thickness”. Ergonomics 33/1, pp. 67-84.

Havenith, G., Holmér, I. And Parsons, K., 2002, Personal factors in thermal comfort assessment: clothing properties and metabolic heat production, Energy and Buildings, 34, 581-591.

Havenith, G., Holmér, I., Den Hartog, E.A. And Parsons, K.C., 1988, Clothing Evaporative Heat Resistance — Proposal for Improved Representation in Standards and Models, Environmental Ergonomics,1998, ICEE, Heaney J. and Hodgdon J. eds., San Diego, 1998

Havenith, G., Nilsson, H., 2004, Correction of clothing insulation for movement and wind effects, a meta-analysis, Eur. J. Appl. Physiol. 92: 636–640

Havenith, G., Nilsson, H., 2005, Correction of clothing insulation for movement and wind effects, a meta-analysis, Eur. J. Appl. Physiol., 93: 506 [Erratum to previous publication]

Holmér I, Nilsson H, Havenith G, Parsons KC, 1999, Clothing convective heat exchange—proposal for improved prediction in standards and models. Ann Occup Hyg 43:329–337

ISO 15831 2004 Clothing —Physiological effects — Measurement of thermal insulation by means of a thermal manikin. International Standard Organization, Switzerland.

ISO 7730, 2005, Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria, International Standardisation Organisation, Geneva.

ISO 9920, 2009, Ergonomics of the thermal environment. Estimation of the thermal insulation and evaporative resistance of a clothing ensemble, International Standardisation Organisation, Geneva.

Kuklane K. Mariann Sandsund, Randi E. Reinertsen, Yutaka Tochihara, Takako Fukazawa, Ingvar Holmér (2004) Comparison of thermal manikins of different body shapes and size; European Journal of Applied Physiology, Volume 92, Issue 6, pp 683-688

Kuklane K. Chuansi Gao; Ingvar Holmér; Lina Giedraityte; Peter Bröde; Victor Candas; Emiel den Hartog; Harriet Meinander; Mark Richards; George Havenith, 2007, Calculation of clothing insulation by serial and parallel methods: effects on clothing choice by IREQ and thermal responses in the cold. International journal of occupational safety and ergonomics: JOSE 2007;13(2):103-16.

Kuklane K. Faming Wang; Chuansi Gao; Ingvar Holmér, 2012, Parallel and serial methods of calculating thermal insulation in European manikin standards. International journal of occupational safety and ergonomics: JOSE 2012;18(2):171-9.

Kwok, A.G., and Chun, C., 2003.Thermal comfort in Japanese schools. Solar Energy 74 (3), 245-252.

McCullough EA, 1993, Factors affecting the resistance to heat transfer provided by clothing‘, Journal of Thermal Biology, 18, Issues 5-6, 1993, 405-407.

McCullough EA, Huang J, Deaton S, 2005 Methods for measuring the clothing area factor. Environmental Ergonomics 2005 (Proceedings of the International Conference on Environmental Ergonomics). Editors I Holmér, K Kuklane and C Gao. Lund University, Lund, Sweden, 2005. ISBN 91-631-7062-0, page 433-436.

McCullough, E.A., Jones, B.W., 1984. A comprehensive data base for estimating clothing insulation. Institute Environ. Research IER technical report 84-01.

McCullough, EA, Jones, B.W., Huck, J., 1985.A comprehensive data base for estimating clothing insulation. ASHRAE Transactions 91 (2), 29-47.

Olesen, B.W., Nielsen, R., 1983. Thermal insulation of clothing measured on moveable manikin and on human subjects. Technical University of Denmark. ECSC Programme Research, 914.

Qian & Fan, 2006, Prediction of Clothing Thermal Insulation and Moisture Vapour Resistance of the Clothed Body Walking in Wind, 2006, Ann. Occup. Hyg., Vol. 50, No. 8, pp. 833–842.

Qian, X.M. and Fan, J, 2009, A Quasi-physical Model for Prediction of Clothing Thermal Insulation and Moisture Vapour Resistance, Applied Ergonomics, 40, 577-590.

Seppanen, O., McNall, P., Munson, D., Sprague, C., 1972. Thermal insulation values for typical indoor clothing ensembles. ASHRAE Transactions 78 (1), 120-130.

Shkolnik A, Taylor CA, Finch V & Borut (1980) Why do Bedouins wear black robes in hot deserts?, Nature 283, 373 - 375 (24 January 1980); doi:10.1038/283373a0

Sprague, C. H., Munson, D.M., 1974. A composite ensemble method for estimating thermal insulation values of clothing. ASHRAE Transactions 80 (1), 120-129.

Wu, Y. S., Fan, J.T., and Yu, W. M. Effect of posture positions on the evaporative resistance and thermal insulation of clothing, Ergonomics, 54(3), 301-313, 2011.

Appendices

Appendix A, Description of the clothing ensembles.

Appendix B, Description of the individual items in the clothing ensembles.

Appendix C, Clothing selection report.

Appendix D, Description of the test procedure for f_{cl}.

Appendix E, air velocity distribution data.

1504-TRP
Extension of the Clothing Insulation Database for Standard 55 and ISO 7730 to provide data for Non-Western Clothing Ensembles, including data on the effect of posture and air movement on that insulation

APPENDIX A
List and description of the ensembles tested

Calibration ensemble			
Ensemble reference	***Gender***	***Country***	***Variations***
ASTM	Male/Female	-	-

Ensemble description			
Item name	***Weight (kg)***	***Material***	***Notes***
Men's briefs T-shirt Protective Nomex III Pants Protective Nomex III Shirt Socks Athletic shoes	0.064 0.150 0.449 0.430 0.069 0.540	Cotton Cotton Nomex Nomex Cotton Suede + nylon	*Different sizes available to fit the manikin properly*

Photos

Trousers fitting

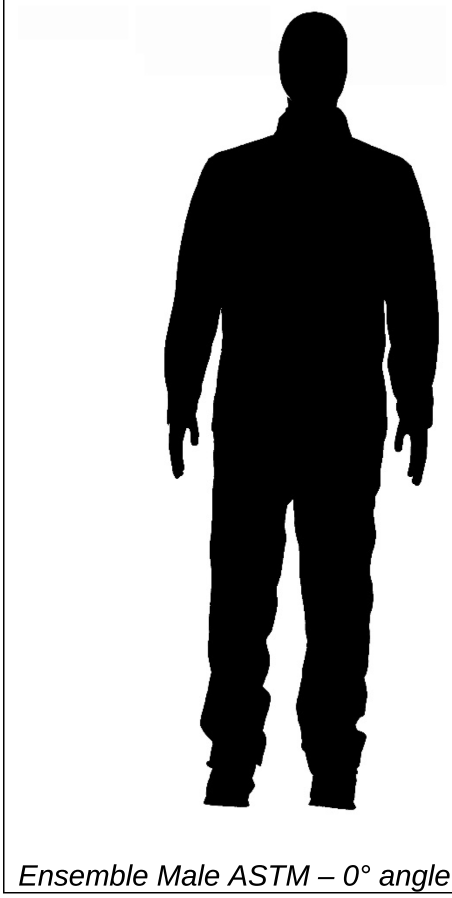
Full ensemble (Front)

Sleeve fitting

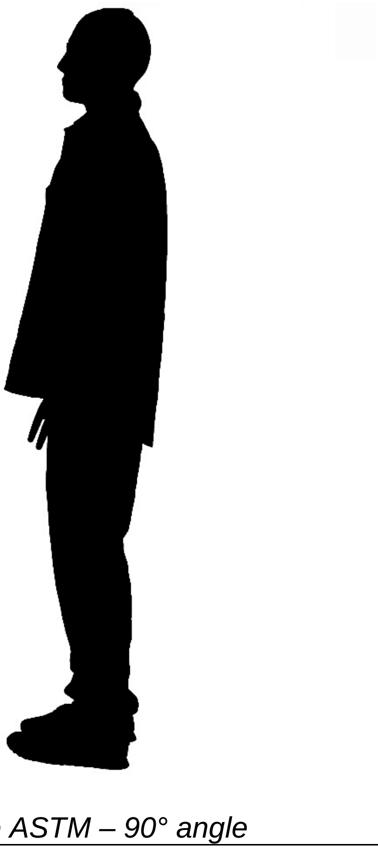
Photos for fcl measurement

Ensemble ASTM Female – 0° angle

Ensemble ASTM – 90° angle



Ensemble Male ASTM – 0° angle



Ensemble ASTM – 90° angle

Ensemble A			
Ensemble reference	***Gender***	***Country***	***Variations***
A (A1 & A2)	Female	Pakistan	A1 – without scarf A2 – with scarf

Ensemble description			
Item name	***Weight (kg)***	***Material***	***Notes***
Women's briefs Bra Shalwar (Pants) Kameez (shirt) Scarf (A2 only) Female sandals	0.025 0.029 0.113 0.316 0.137 0.245	cotton cotton polycotton polycotton polycotton suede + plastic	*Scarf worn draped evenly around the neck and over the shoulders*

Photos (*A2 – with scarf*)

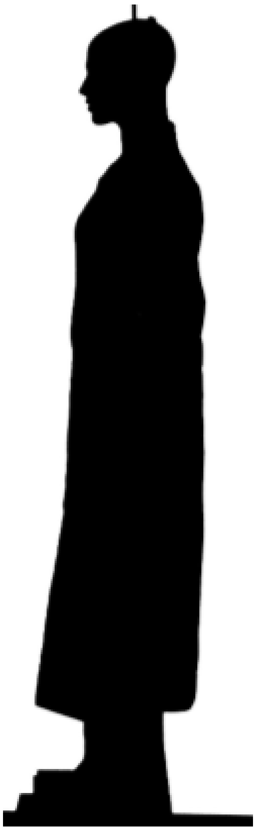
Front

Profile

Back

Photos for fcl measurement

Ensemble A1 – 0° angle



Ensemble A1 – 90° angle

Ensemble A2 – 0° angle

Ensemble A2 – 90° angle

Ensemble B

Ensemble reference	*Gender*	*Country*	*Variations*
B (B1 & B2)	Female	India	B1 – without scarf B2 – with scarf

Ensemble description

Item name	*Weight (kg)*	*Material*	*Notes*
Women's briefs Bra Shalwar (Pants) Kameez (shirt) Scarf (A2 only) Female sandals	0.025 0.029 0.160 0.280 0.120 0.245	cotton cotton polyester polyester polyester suede + plastic	*Scarf worn draped evenly around the neck and over the shoulders*

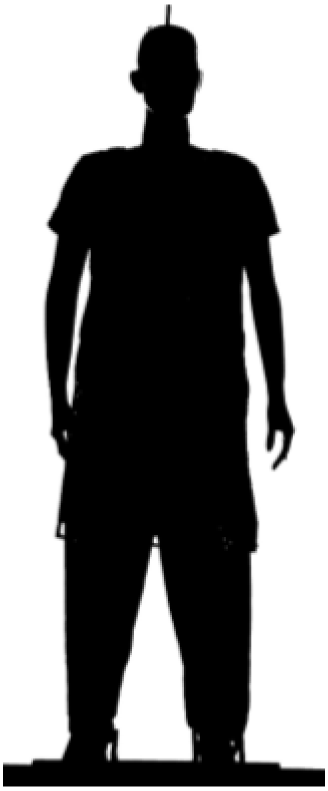
Photos (*B2 – with scarf*)

Front

Back

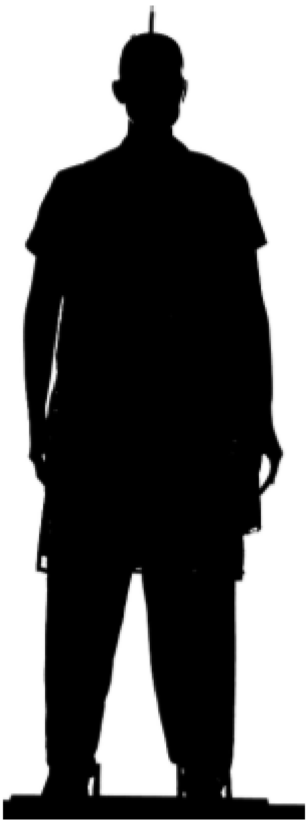
Pants fitting

Photos for fcl measurement

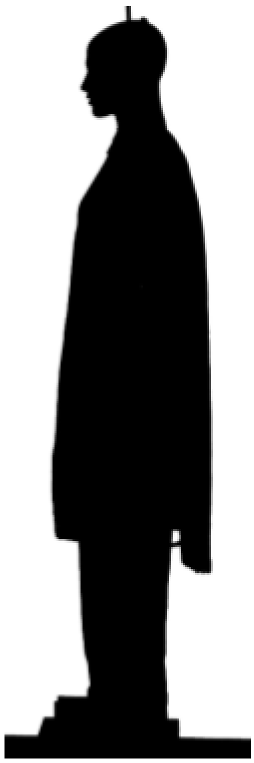


Ensemble B1 – 0° angle

Ensemble B1 – 90° angle



Ensemble B2 – 0° angle



Ensemble B2 – 90° angle

Ensemble C			
Ensemble reference	***Gender***	***Country***	***Variations***
C	Male	Pakistan	
Ensemble description			
Item name	***Weight (kg)***	***Material***	***Notes***
Men's briefs Shalwar (Pants) Kameez (shirt) Socks Athletic shoes	0.064 0.195 0.276 0.037 0.540	cotton polycotton polycotton cotton suede + nylon	
Photos			

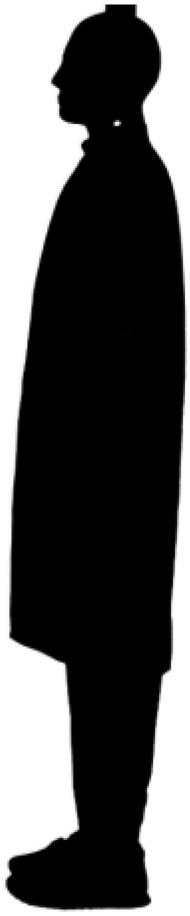
Front

Profile

Back

Photos for fcl measurement

Ensemble C - 0° angle



Ensemble C - 90° angle

Ensemble D

Ensemble reference	*Gender*	*Country*	*Variations*
D (D1 & D2)	Female	Pakistan	D1 – without scarf D2 – with scarf

Ensemble description

Item name	*Weight (kg)*	*Material*	*Notes*
Women's briefs Bra Shalwar (Pants) Kameez (shirt) Scarf (***D2 only***) Female sandals	0.025 0.029 0.150 0.194 0.128 0.245	cotton cotton cotton cotton + polyester polyester suede + plastic	*Scarf worn draped evenly around the neck and over the shoulders*

Photos (*D2 – with scarf*)

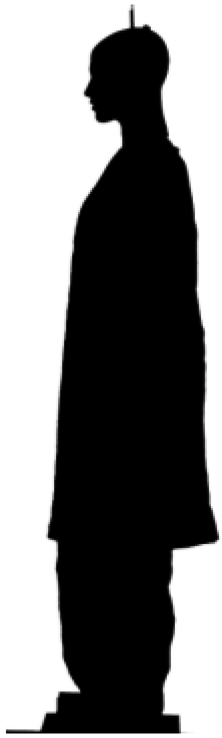
Front

Profile

Back

Photos for fcl measurement

Ensemble D1 – 0° angle



Ensemble D1 – 90° angle

Ensemble D2 – 0° angle

Ensemble D2 – 90° angle

Ensemble E

Ensemble reference	*Gender*	*Country*	*Variations*
E	Male	India/Pakistan	

Ensemble description

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs Shalwar (Pants) Kameez (shirt) Socks Athletic shoes	0.064 0.296 0.506 0.037 0.540	cotton polycotton polyester cotton suede + nylon	

Photos

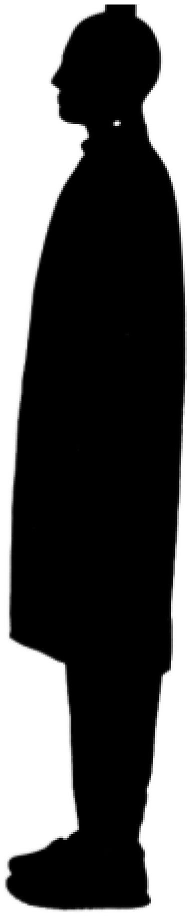

Front


Profile


Back

Photos for fcl measurement

Ensemble E - 0° angle



Ensemble E - 90° angle

Ensemble F1

Ensemble reference	*Gender*	*Country*	*Variations*
F (F1, F2, F3, F4, F5 & F6)	Female	Pakistan	See individual descriptions

Ensemble description (*F1*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra Women's briefs Stretched body Over-shirt Jeans Abaya (long dress) ***Long Fitted Hijab*** Socks Athletic shoes	0.029 0.025 0.152 0.130 0.390 0.466 0.248 0.037 0.540	cotton cotton polycotton polycotton cotton + lycra polyester synthetic nylon cotton suede + nylon	**For photos of the base layer (underneath the Abaya) see ensemble L2**

Photos (*F1*)


Front

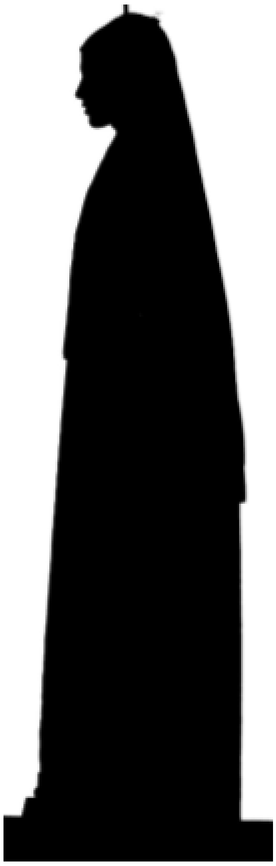

Profile


Back


Hijab

Photos for fcl measurement

Ensemble F1 - 0° angle



Ensemble F1 - 90° angle

Ensemble F2			
Ensemble reference	***Gender***	***Country***	***Variations***
F (F1, F2, F3, F4, F5 & F6)	Female	Pakistan	See individual descriptions

Ensemble description (*F2*)			
Item name	***Weight (kg)***	***Material***	***Notes***
Bra Women's briefs Stretched body Over-shirt Jeans Abaya (long dress) ***<u>Short traditional hijab</u>*** Socks Athletic shoes	0.029 0.025 0.152 0.130 0.390 0.466 0.063 0.037 0.540	cotton cotton polycotton polycotton cotton + lycra polyester woven viscose cotton suede + nylon	**For photos of the base layer (underneath the Abaya) see ensemble L2**

Photos (*F2*)

Front

Hijab (front)

Hijab (back)

Photos for fcl measurement

Ensemble F2 - 0° angle

Ensemble F2 - 90° angle

Ensemble F3

Ensemble reference	*Gender*	*Country*	*Variations*
F (F1, F2, F3, F4, F5 & F6)	Female	Pakistan	See individual descriptions

Ensemble description (*F3*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra Women's briefs Stretched body Over-shirt Jeans Abaya (long dress) ***Long traditional hijab*** Socks Athletic shoes	0.029 0.025 0.152 0.130 0.390 0.466 0.081 0.037 0.540	cotton cotton polycotton polycotton cotton + lycra polyester cotton cotton suede + nylon	**For photos of the base layer (underneath the Abaya) see ensemble L2**

Photos (*F3*)


Front


Profile


Back


Hijab

Photos for fcl measurement

Ensemble F3 - 0° angle

Ensemble F3 - 90° angle

Ensemble F4

Ensemble reference	*Gender*	*Country*	*Variations*
F (F1, F2, F3, F4, F5 & F6)	Female	Pakistan	See individual descriptions

Ensemble description (*F4*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra	0.029	cotton	**For photos of the base layer (underneath the Abaya) see ensemble L1**
Women's briefs	0.025	cotton	
Over-shirt	0.130	polycotton	
Jeans	0.390	cotton + lycra	
Abaya (long dress)	0.466	polyester	
Long traditional hijab	0.081	cotton	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos (*F4*)


Front

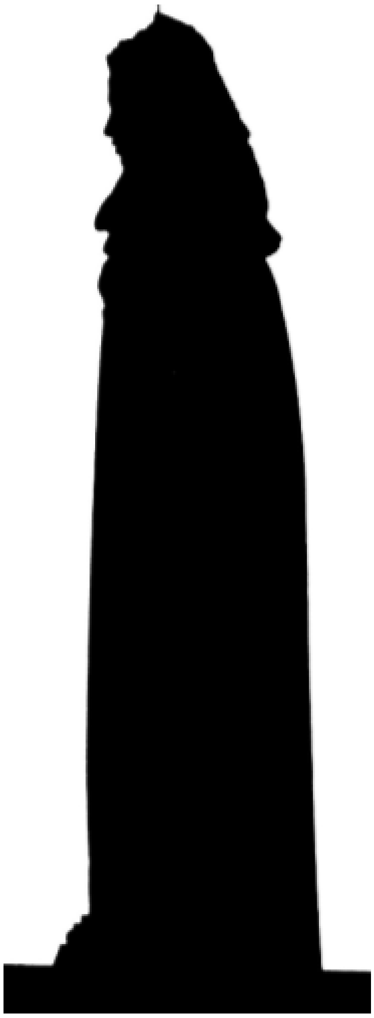

Profile


Back


Hijab

Photos for fcl measurement

Ensemble F4 - 0° angle



Ensemble F4 - 90° angle

Ensemble F5

Ensemble reference	*Gender*	*Country*	*Variations*
F (F1, F2, F3, F4, F5 & F6)	Female	Pakistan	See individual descriptions

Ensemble description (*F5*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra	0.029	cotton	**For photos of the base layer (underneath the Abaya) see ensemble L2**
Women's briefs	0.025	cotton	
Stretched body	0.152	polycotton	
Over-shirt	0.130	polycotton	
Jeans	0.390	cotton + lycra	
Abaya (long dress)	0.466	polyester	
Short fitted hijab	0.075	knitted nylon + lycra	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos (*F5*)


Front


Profile


Back


Hijab

Photos for fcl measurement

Ensemble F5 - 0° angle

Ensemble F5 - 90° angle

Ensemble F6

Ensemble reference	*Gender*	*Country*	*Variations*
F (F1, F2, F3, F4, F5 & F6)	Female	Pakistan	See individual descriptions

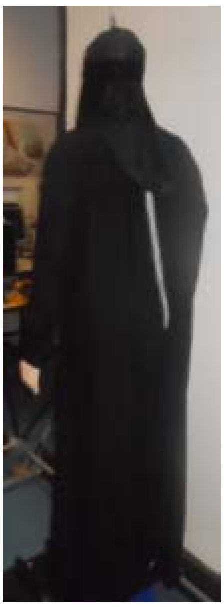
Ensemble description (*F6*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra	0.029	cotton	**For photos of the base layer (underneath the Abaya) see ensemble L2**
Women's briefs	0.025	cotton	
Stretched body	0.152	polycotton	
Over-shirt	0.130	polycotton	
Jeans	0.390	cotton + lycra	
Abaya (long dress)	0.466	polyester	
Short fitted hijab	0.075	knitted nylon + lycra	
Burka	0.034	viscose	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos (*F6*)


Front

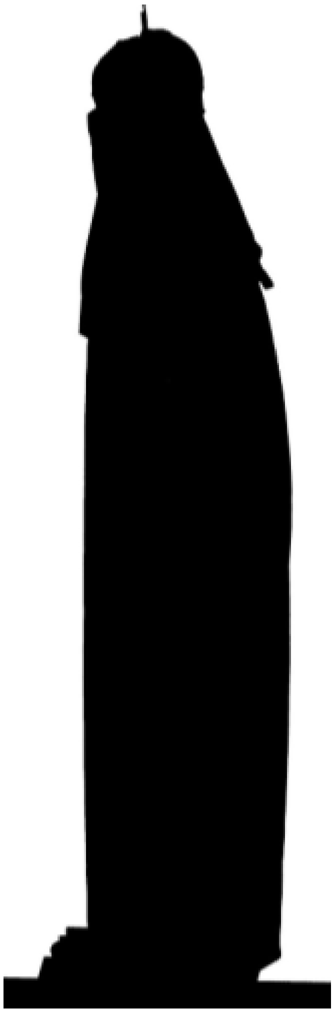

Profile


Back


Hijab + Burka

Photos for fcl measurement

Ensemble F6 - 0° angle



Ensemble F6 - 90° angle

Ensemble G1

Ensemble reference	*Gender*	*Country*	*Variations*
G (G1, G2 & G3)	Female	Indonesia	G1 – without scarf G2 – with scarf G3 – with scarf, no jacket

Ensemble description (*G1*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra Women's briefs Long-sleeved shirt Suit Pants Suit jacket Socks Athletic shoes	0.029 0.025 0.204 0.354 0.486 0.037 0.540	cotton cotton polycotton polyester polyester cotton suede + nylon	Shirt closed to top button and tucked into Pants. Jacket closed to top button

Photos (*G1*)

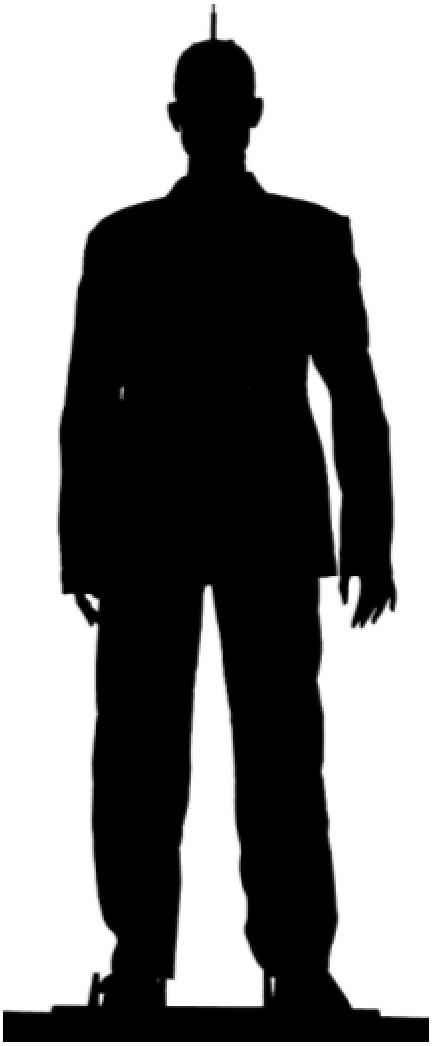

Front


Profile


Back

Note: The headband was used to attach the headscarf in G2 & G3.

Photos for fcl measurement



Ensemble G1 – 0° angle

Ensemble G1 – 90° angle

Ensemble G2

Ensemble reference	Gender	Country	Variations
G (G1, G2 & G3)	Female	Indonesia	G1 – without scarf G2 – with scarf G3 – with scarf, no jacket

Ensemble description (*G2*)

Item name	Weight (kg)	Material	Notes
Bra	0.029	cotton	Shirt closed to top button and tucked into Pants.
Women's briefs	0.025	cotton	
Long-sleeved shirt	0.204	polycotton	
Hijab	0.060	cotton	
Suit Pants	0.354	polyester	Jacket closed to top button
Suit jacket	0.486	polyester	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos (*G2*)


Front


Profile


Back

Photos for fcl measurement

Ensemble G2 – 0° angle

Ensemble G2 – 90° angle

Ensemble G3

Ensemble reference	*Gender*	*Country*	*Variations*
G (G1, G2 & G3)	Female	Indonesia	G1 – without scarf G2 – with scarf G3 – with scarf, no jacket

Ensemble description (*G3*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra Women's briefs Long-sleeved shirt Suit Pants Hijab Socks Athletic shoes	0.029 0.025 0.204 0.354 0.060 0.037 0.540	cotton cotton polycotton polyester cotton cotton suede + nylon	Shirt closed to top button and tucked into Pants.

Photos (*G3*)

Front

Profile

Back

Photos for fcl measurement

Ensemble G2 – 0° angle

Ensemble G2 – 90° angle

Ensemble H			
Ensemble reference	***Gender***	***Country***	***Variations***
H (H1 & H2)	Female	Indonesia	H1 – without scarf H2 – with scarf

Ensemble description (*H2*)			
Item name	***Weight (kg)***	***Material***	***Notes***
Bra Women's briefs Long-sleeved shirt Skirt Headscarf (***H2 only***) Socks Athletic shoes	0.029 0.025 0.204 0.357 0.060 0.037 0.540	cotton cotton polycotton polycotton cotton cotton suede + nylon	Shirt closed to top button and tucked into skirt

Photos (*H2*)

Front

Back

Headscarf

Photos for fcl measurement

Ensemble H1 – 0° angle

Ensemble H1 – 90° angle

Ensemble H2 – 0° angle

Ensemble H2 – 90° angle

Ensemble I			
Ensemble reference	***Gender***	***Country***	***Variations***
I	Male	Indonesia	

Ensemble description			
Item name	***Weight (kg)***	***Material***	***Notes***
Men's briefs Work shirt Work Pants Socks Athletic shoes	0.064 0.379 0.508 0.037 0.540	cotton polycotton polyester cotton suede + nylon	

Photos

Front

Profile

Back

Photos for fcl measurement

Ensemble I - 0° angle

Ensemble I - 90° angle

Ensemble J1			
Ensemble reference	***Gender***	***Country***	***Variations***
J	Male	Kuwait	J1, J2 & J3 (see individual descriptions)

Ensemble description (*J1*)

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs	0.064	cotton	
Dishdasha (thowb)	0.721	microfiber polyester	
Long Pants underwear,	0.230	cotton	
Long sleeve undershirt	0.262	cotton	
Long serwal (Pants)	0.195	polycotton	
Tagiya (hat)	0.017	polycotton	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

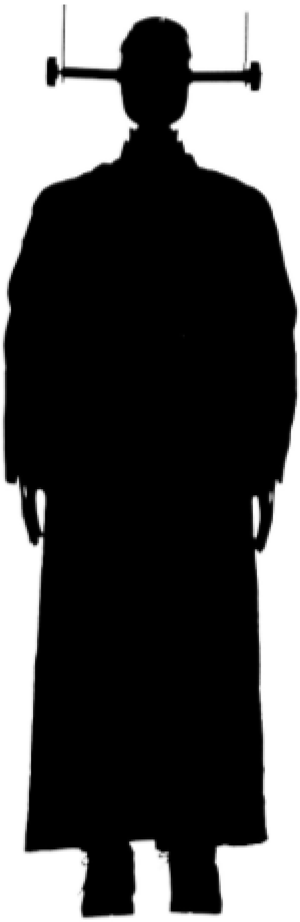
Photos (*J1*)

Undergarment

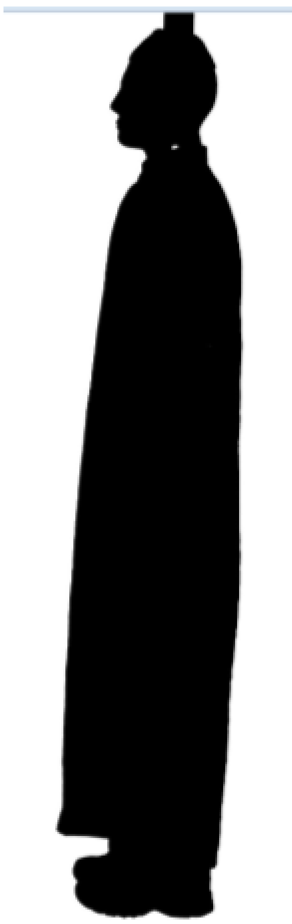
Front

Back

Photos for fcl measurement



Ensemble J1 - 0° angle



Ensemble J1 - 90° angle

Ensemble J2

Ensemble reference	Gender	Country	Variations
J	Male	Kuwait	J1, J2 & J3 (see individual descriptions)

Ensemble description (*J2*)

Item name	Weight (kg)	Material	Notes
Men's briefs	0.064	cotton	
Dishdasha (thowb)	0.437	microfiber polyester	
Long Pants underwear,	0.230	cotton	
Long sleeve undershirt	0.262	cotton	
Long serwal (Pants)	0.195	polycotton	
Tagiya (hat)	0.017	polycotton	
Iqal (black cord)	0.142	plastic	
Ghutra (headdress)	0.156	cotton	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

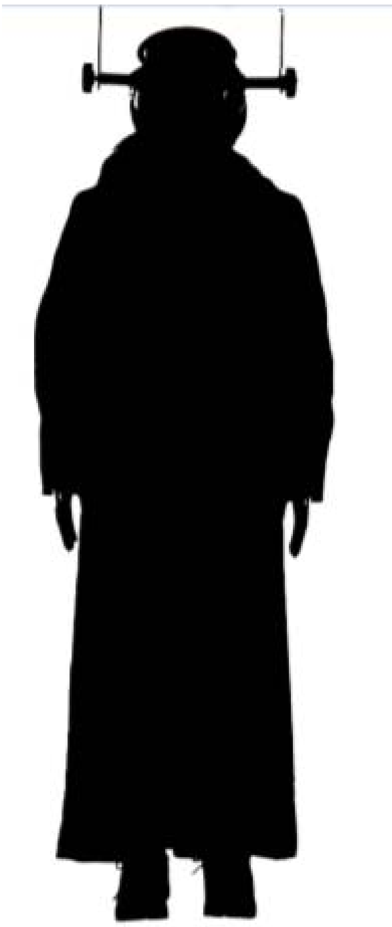
Photos (*J2*)

Front

Back

Iqal, Ghutra & Tagiya(underneath)

Photos for fcl measurement



Ensemble J2 - 0° angle

Ensemble J2- 90° angle

Ensemble J3

Ensemble reference	Gender	Country	Variations
J	Male	Kuwait	J1, J2 & J3 (see individual descriptions)

Ensemble description (*J3*)

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs	0.064	cotton	Scarf is worn outside coat
Dishdasha (thowb)	0.437	microfiber polyester	
Long Pants underwear,	0.230	cotton	
Long sleeve undershirt	0.262	cotton	
Long serwal (Pants)	0.195	polycotton	
Tagiya (hat)	0.017	polycotton	
Iqal (black cord)	0.142	plastic	
Ghutra (headscarf	0.156	cotton	
Coat	0.458	viscose	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos (*J3*)

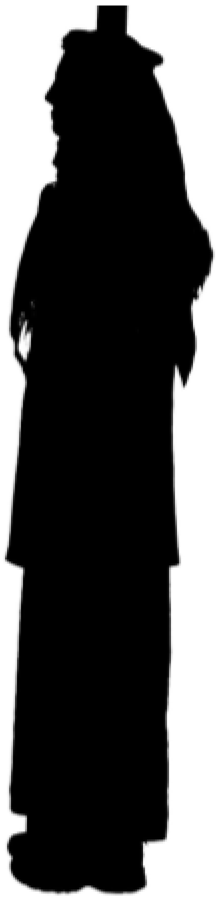
Front

Back

Iqal, Ghutra & Tagiya(underneath)

Photos for fcl measurement

Ensemble J3 - 0° angle



Ensemble J3- 90° angle

Ensemble K1

Ensemble reference	*Gender*	*Country*	*Variations*
K	Male	Kuwait	K1, K2 & K3 (see individual descriptions)

Ensemble description (*K1*)

Item name	*Weight (kg)*	*Material*	*Notes*
Men’s briefs	0.064	cotton	
Dishdasha (thowb)	0.437	polycotton	
Short sleeved t-shirt	0.152	polycotton	
Long serwal (Pants)	0.195	polycotton	
Tagiya (hat)	0.017	polycotton	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos (*K1*)

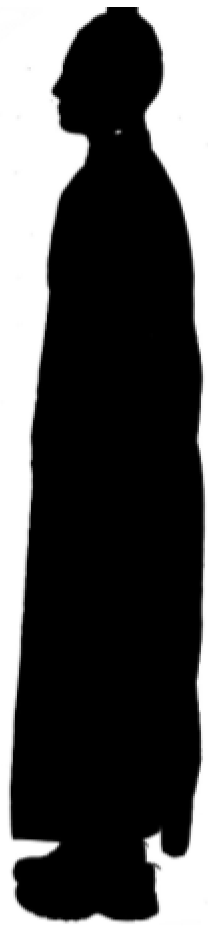
Undergarment

Front

Back

Photos for fcl measurement

Ensemble K1 - 0° angle



Ensemble K1 - 90° angle

Ensemble K2

Ensemble reference	*Gender*	*Country*	*Variations*
K	Male	Kuwait	K1, K2 & K3 (see individual descriptions)

Ensemble description (*K2*)

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs	0.064	cotton	
Dishdasha (thowb)	0.437	polycotton	
Short sleeved t-shirt	0.152	polycotton	
Long serwal (Pants)	0.195	polycotton	
Tagiya (hat)	0.017	polycotton	
Iqal (cord)	0.142	plastic	
Ghutra (headdress)	0.156	cotton	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

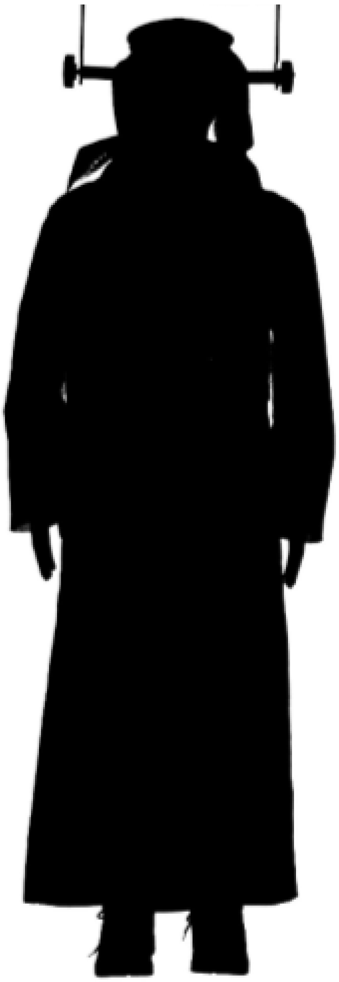
Photos (*K2*)

Front

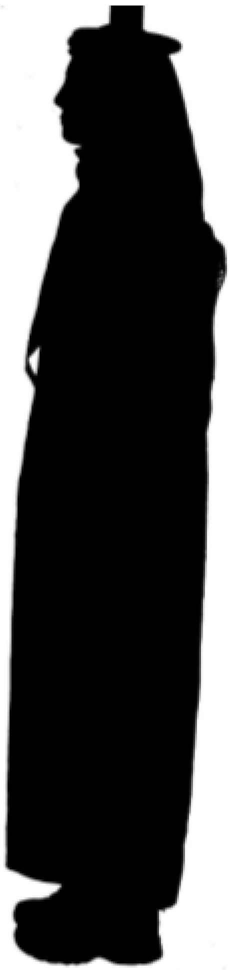
Profile

Back

Photos for fcl measurement



Ensemble K2 - 0° angle



Ensemble K2- 90° angle

Ensemble K3

Ensemble reference	Gender	Country	Variations
K	Male	Kuwait	K1, K2 & K3 (see individual descriptions)

Ensemble description (*K3*)

Item name	Weight (kg)	Material	Notes
Men's briefs	0.064	cotton	Scarf is worn outside coat
Dishdasha (thowb)	0.437	polycotton	
Short sleeved t-shirt	0.152	polycotton	
Long serwal (Pants)	0.195	polycotton	
Tagiya (hat)	0.017	polycotton	
Iqal (black cord)	0.142	plastic	
Ghutra (headscarf)	0.156	cotton	
Coat	0.458	viscose	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos (*K3*)

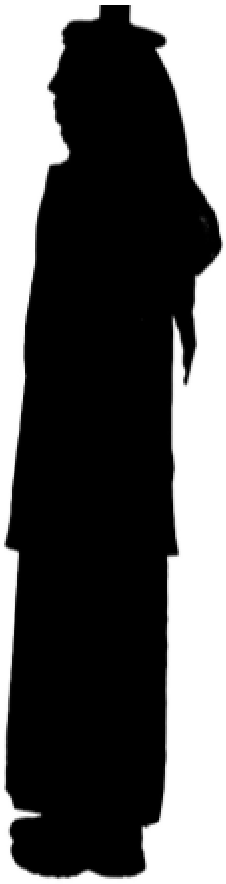
Front

Back

Iqal, Ghutra & Tagiya(underneath)

Photos for fcl measurement

Ensemble K3 - 0° angle



Ensemble K3- 90° angle

Ensemble L1			
Ensemble reference	***Gender***	***Country***	***Variations***
L (L1, L2 & L3)	Female	Kuwait	L1 – without body L2 – with body L3 – with body and with coat

Ensemble description (*L1*)			
Item name	***Weight (kg)***	***Material***	***Notes***
Bra Women's briefs Over-shirt Jeans Anta (= head cover) Hijab (= headscarf) Socks Athletic shoes	0.029 0.025 0.130 0.391 0.030 0.030 0.037 0.540	cotton cotton polycotton cotton + lycra polycotton polyester cotton suede + nylon	**Head cover worn underneath headscarf**

Photos (*L1*)

Front

Profile

Headscarf

Photos for fcl measurement

Ensemble L1 – 0° angle

Ensemble L1 – 90° angle

Ensemble L2			
Ensemble reference	***Gender***	***Country***	***Variations***
L (L1, L2 & L3)	Female	Kuwait	L1 – without body L2 – with~~out~~ body L3 – with body and with coat

Ensemble description (*L2*)			
Item name	***Weight (kg)***	***Material***	***Notes***
Bra	0.029	cotton	**Head cover worn underneath headscarf**
Women's briefs	0.025	cotton	
Stretched body	0.152	polycotton	
Over-shirt	0.130	polycotton	
Jeans	0.391	cotton + lycra	
Anta (= head cover)	0.030	polycotton	
Hijab (= headscarf)	0.030	polyester	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

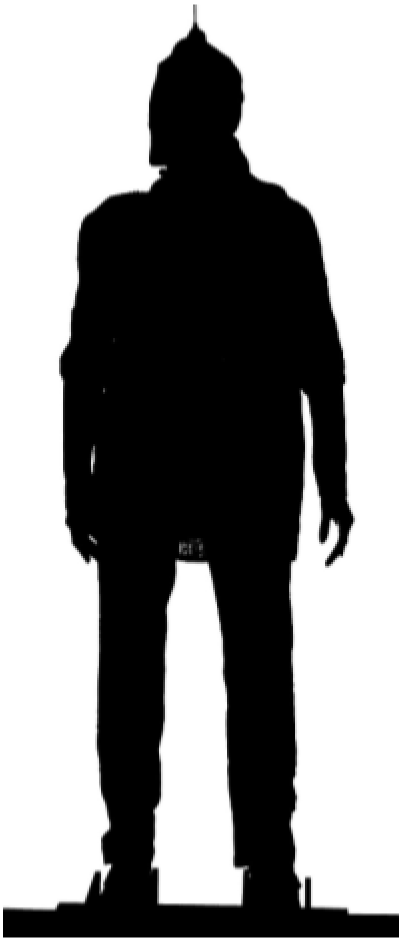
Photos (*L2*)

Front

Profile

Back

Photos for fcl measurement



Ensemble L2 – 0° angle

Ensemble L2 – 90° angle

Ensemble L3

Ensemble reference	***Gender***	***Country***	***Variations***
L (L1, L2 & L3)	Female	Kuwait	L1 – with body L3 – without body L3 – with body and with coat

Ensemble description (*L3*)

Item name	***Weight (kg)***	***Material***	***Notes***
Bra Women's briefs Stretched body Over-shirt Jeans Anta (= head cover) Hijab (= headscarf) Coat Socks Athletic shoes	0.029 0.025 0.152 0.130 0.391 0.030 0.030 0.458 0.037 0.540	cotton cotton polycotton polycotton cotton + lycra polycotton polyester viscose cotton suede + nylon	**Head cover worn underneath headscarf**

Photos (*L3*)

Front

Profile

Back

Photos for fcl measurement


Ensemble L3 – 0° angle


Ensemble L3 – 90° angle

Ensemble M-S

Ensemble reference	*Gender*	*Country*	*Variations*
MS (MS1 & MS2)	Female	Kuwait	MS1 – without headscarf MS2~~1~~ – with headscarf

Ensemble description (*MS2*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra Women's briefs Full slip Double layer Abaya (dress) Anta (= head cover – ***MS2 only***) Hijab (= headscarf - ***MS2 only***) Female sandals	0.029 0.025 0.201 0.801 0.030 0.090 0.245	Cotton Cotton Cotton Polyester Cotton Polyester Suede + plastic	**Head cover worn underneath headscarf**

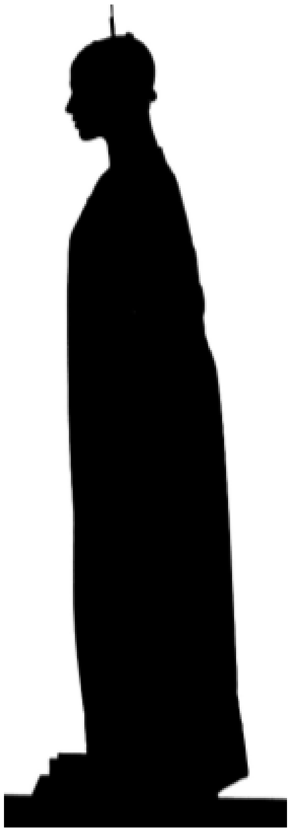
Photos (*MS2*)



Front *Profile* *Back*

Photos for fcl measurement

Ensemble MS1 – 0° angle



Ensemble MS1 – 90° angle

Ensemble MS2 – 0° angle

Ensemble MS2 – 90° angle

Ensemble M-W

Ensemble reference	*Gender*	*Country*	*Variations*
MW (MW1 & MW2)	Female	Kuwait	MW1 – without headscarf MW2~~1~~ – with headscarf

Ensemble description (*MW2*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra	0.029	Cotton	**Head cover worn underneath headscarf**
Women's briefs	0.025	Cotton	
Long Pants underwear,	0.230	Cotton	
Long sleeve undershirt	0.262	Cotton	
Full slip	0.201	Cotton	
Double layer Abaya (dress)	0.801	Polyester	
Anta (= head cover – ***MW2 only)***	0.030	Cotton	
Hijab (= headscarf - ***MW2 only***)	0.090	Polyester	
Socks	0.037	Cotton	
Athletic shoes	0.245	Suede + plastic	

Photos (*MW2*)

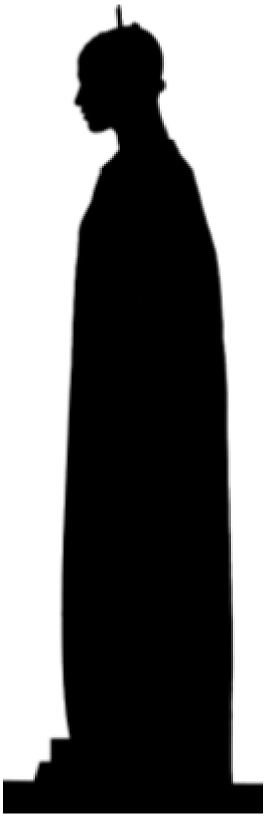

Front


Profile


Back

Photos for fcl measurement

Ensemble MW1 – 0° angle



Ensemble MW1 – 90° angle

Ensemble MW2 – 0° angle

Ensemble MW2 – 90° angle

Ensemble N

Ensemble reference	Gender	Country	Variations
N	Female	Ghana/Nigeria	

Ensemble description

Item name	Weight (kg)	Material	Notes
Bra Women’s briefs Cotton dress Head band Female sandals	0.029 0.025 0.341 0.049 0.245	cotton cotton cotton cotton suede + plastic	

Photos

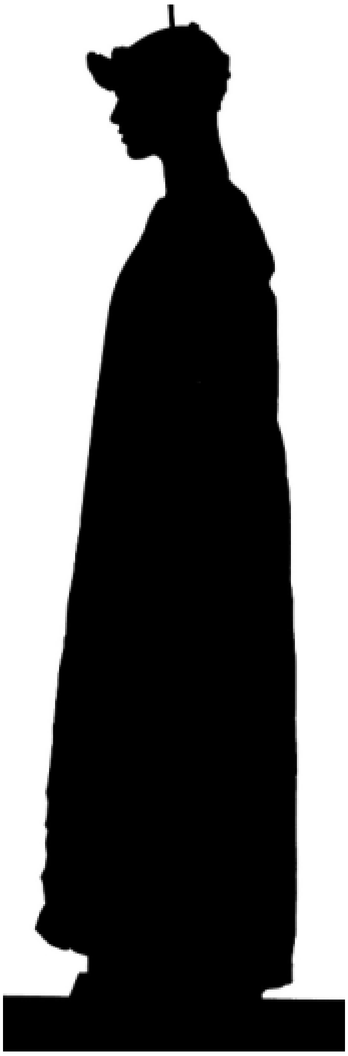
Front

Profile

Back

Photos for fcl measurement

Ensemble N - 0° angle



Ensemble N - 90° angle

Ensemble O

Ensemble reference	Gender	Country	Variations
O	Female	Ghana/Nigeria	

Ensemble description

Item name	Weight (kg)	Material	Notes
Bra Women's briefs Long shirt Long Pants Female sandals	0.029 0.025 0.282 0.223 0.245	cotton cotton cotton cotton suede + plastic	

Photos

Front

Pants fitting

Back

Photos for fcl measurement

Ensemble N - 0° angle

Ensemble N - 90° angle

Ensemble P			
Ensemble reference	***Gender***	***Country***	***Variations***
P	Male	Ghana/Nigeria	

Ensemble description			
Item name	***Weight (kg)***	***Material***	***Notes***
Men's briefs Short shirt with long sleeves Long Pants Male sandals	0.064 0.200 0.199 0.589	cotton cotton cotton leather + plastic	

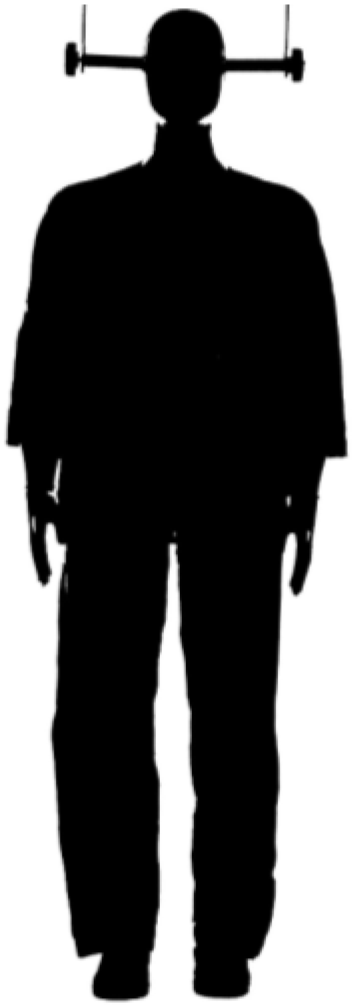
Photos

Front

Profile

Back

Photos for fcl measurement



Ensemble P - 0° angle

Ensemble P - 90° angle

Ensemble Q

Ensemble reference	Gender	Country	Variations
Q	Male	Ghana/Nigeria	

Ensemble description

Item name	Weight (kg)	Material	Notes
Men's briefs Short shirt with short sleeves Long Pants Male sandals	0.064 0.203 0.199 0.589	cotton cotton cotton leather + plastic	

Photos

Front

Profile

Back

Photos for fcl measurement

Ensemble Q - 0° angle

Ensemble Q - 90° angle

Ensemble R

Ensemble reference	*Gender*	*Country*	*Variations*
R	Male	Ghana/Nigeria	

Ensemble description

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs	0.064	cotton	
Short shirt with long sleeves	0.200	cotton	
Long Pants	0.199	cotton	
"Boubou"(wide sleeved robe)	0.698	cotton	
African hat	0.068	cotton	
Male sandals	0.589	leather + plastic	

Photos

Front

Profile

Back

Photos for fcl measurement

Ensemble R - 0° angle

Ensemble R - 90° angle

Ensemble S			
Ensemble reference	***Gender***	***Country***	***Variations***
S	Female	Ghana/Nigeria	

Ensemble description

Item name	*Weight (kg)*	*Material*	*Notes*
Bra Women's briefs Short shirt with long sleeves Long Pants Female sandals	0.029 0.025 0.200 0.223 0.245	cotton cotton cotton cotton suede + plastic	

Photos


Front


Profile


Back

Photos for fcl measurement

Ensemble S - 0° angle

Ensemble S - 90° angle

Ensemble T

Ensemble reference	*Gender*	*Country*	*Variations*
T	Male	Ghana/Nigeria	

Ensemble description

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs Short shirt with long sleeves Shorts Male sandals	0.064 0.200 0.127 0.589	cotton cotton cotton leather + plastic	

Photos

Front

Profile

Back

Photos for fcl measurement

Ensemble T - 0° angle

Ensemble T - 90° angle

Ensemble U

Ensemble reference	*Gender*	*Country*	*Variations*
U	Male	Ghana/Nigeria	

Ensemble description

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs Long Shirt Long Pants African hat Male sandals	0.064 0.282 0.199 0.068 0.589	cotton cotton cotton cotton leather + plastic	

Photos

Front

Profile

Back

Photos for fcl measurement

Ensemble T - 0° angle

Ensemble T - 90° angle

Ensemble V

Ensemble reference	*Gender*	*Country*	*Variations*
V	Male	Pakistan	V1 – without underwear Pants, undershirt & coat V2 – with underwear Pants & undershirt but no coat V3 - with underwear Pants, undershirt & coat

Ensemble description (*V1*)

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs	0.064	Cotton	
Large Pants	0.593	Polycotton	
Matching long shirt	0.585	Polycotton	
Socks	0.037	Cotton	
Athletic shoes	0.540	Suede + cotton	

Photo (*V1*)

Front

Photos for fcl measurement

Ensemble V1- 0° angle

Ensemble V1 - 90° angle

Ensemble V

Ensemble reference	*Gender*	*Country*	*Variations*
V	Male	Pakistan	V1 – without underwear Pants, undershirt & coat V2 – with underwear Pants & undershirt but no coat V3 - with underwear Pants, undershirt & coat

Ensemble description (*V2*)

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs Long pants underwear Long sleeved undershirt Large pants Matching long shirt Socks Athletic shoes	0.064 0.230 0.262 0.593 0.585 0.037 0.540	Cotton Cotton Cotton Polycotton Polycotton Cotton Suede + cotton	**The undergarment is the same as used in J2&J3**

Photo (*V2*)

Front

Photos for fcl measurement

Ensemble V2- 0° angle

Ensemble V2 - 90° angle

Ensemble V

Ensemble reference	*Gender*	*Country*	*Variations*
V	Male	Pakistan	V1 – without underwear Pants, undershirt & coat V2 – with underwear Pants & undershirt but no coat V3 - with underwear Pants, undershirt & coat

Ensemble description (*V3*)

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs Long Pants underwear Long sleeved undershirt Large Pants Matching long shirt Coat Socks Athletic shoes	0.064 0.230 0.262 0.593 0.585 0.458 0.037 0.540	Cotton Cotton Cotton Polycotton Polycotton Viscose Cotton Suede + cotton	**The undergarment is the same as used in J2&J3**

Photo (*V3*)

Front

Photos for fcl measurement

Ensemble V3- 0° angle

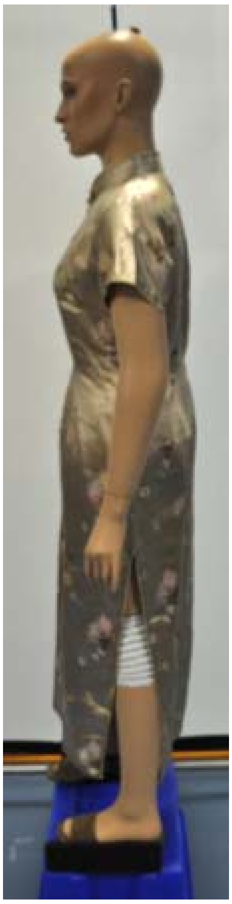
Ensemble V3- 90° angle

Ensemble W			
Ensemble reference	***Gender***	***Country***	***Variations***
W	Female	China	

Ensemble description			
Item name	***Weight (kg)***	***Material***	***Notes***
Bra Women's briefs Camisole Short sleeved Qipao (= Chinese dress) Female sandals	0.029 0.025 0.077 0.221 0.245	Cotton Cotton Polycotton Satin polyester Suede + plastic	

Photos

Front



Profile

Back

Photos for fcl measurement

Ensemble W - 0° angle

Ensemble W - 90° angle

Ensemble X1

Ensemble reference	*Gender*	*Country*	*Variations*
X	Female	India	X1 – without shirt and towel X2 – with shirt and towel

Ensemble description (*X1*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra	0.029	cotton	
Women's briefs	0.025	cotton	
Churidhar Pants	0.105	polycotton	
Churidhar dress	0.090	cotton	
Shawl	0.051	polyester	
Female sandals	0.245	suede + plastic	

Photos (*X1*)

Front

Profile

Back

Photos for fcl measurement

Ensemble X1 - 0° angle

Ensemble X1 - 90° angle

Ensemble X2

Ensemble reference	*Gender*	*Country*	*Variations*
X	Female	India	X1 – without shirt and towel X2 – with shirt and towel

Ensemble description (*X2*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra	0.029	cotton	
Women's briefs	0.025	cotton	
Churidhar Pants	0.105	polycotton	
Churidhar dress	0.090	cotton	
Shirt	0.208	man-made acetate	
Shawl	0.051	polyester	
Towel (head)	0.206	cotton	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos (*X2*)


Front


Profile


Back

Photos for fcl measurement

Ensemble X2 - 0° angle

Ensemble X2 - 90° angle

Ensemble Y1

Ensemble reference	*Gender*	*Country*	*Variations*
Y	Female	India	Y1 – without shirt and towel Y2 – with shirt and towel

Ensemble description (*Y1*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra	0.029	cotton	
Women's briefs	0.025	cotton	
Underskirt	0.143	cotton	
Blouse	0.041	cotton	
Saree	0.275	synthetic polyester	
Female sandals	0.245	suede + plastic	

Photos (*Y1*)



Front	Profile	Back

Photos for fcl measurement

Ensemble Y1 - 0° angle

Ensemble Y1 - 90° angle

Ensemble Y2

Ensemble reference	*Gender*	*Country*	*Variations*
Y	Female	India	Y1 – without shirt and towel Y2 – with shirt and towel

Ensemble description (*Y2*)

Item name	*Weight (kg)*	*Material*	*Notes*
Bra Women's briefs Underskirt Blouse Saree Shirt Towel (head) Socks Athletic shoes	0.029 0.025 0.143 0.041 0.275 0.208 0.206 0.037 0.540	cotton cotton cotton cotton synthetic polyester man-made acetate cotton cotton suede + nylon	**Please note that the Athletic shoes were used for the insulation measurements (not the sandals as shown on the photos)**

Photos (*Y2*)


Front


Profile


Back

Photos for fcl measurement

Ensemble Y2 - 0° angle

Ensemble Y2 - 90° angle

Ensemble Z

Ensemble reference	*Gender*	*Country*	*Variations*
Z	Male	India	

Ensemble description

Item name	*Weight (kg)*	*Material*	*Notes*
Men's briefs	0.064	cotton	
Pants	0.379	polyester	
"Bananian" (=vest)	0.078	cotton	
Shirt	0.208	man-made acetate	
Towel (head)	0.206	cotton	
Socks	0.037	cotton	
Athletic shoes	0.540	suede + nylon	

Photos

Front

Profile

Back

Photos for fcl measurement

Ensemble Z - 0° angle

Ensemble Z - 90° angle

ASHRAE Research Project

1504-TRP
Extension of the Clothing Insulation Database for Standard 55 and ISO 7730 to provide data for Non-Western Clothing Ensembles, including data on the effect of posture and air movement on that insulation

Appendix B
List and description of the individual items in ensembles tested

<table>
<tr><td>Ensemble ref</td><td>A1 + A2</td><td>Country</td><td>Pakistan</td></tr>
<tr><td>Gender</td><td>Female</td><td></td><td></td></tr>
<tr><td colspan="4">  
</td></tr>
<tr><td>Description</td><td>Shalwar(Pants)
Kameez (shirt)
Scarf</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Underwear</td><td>Bra
Briefs</td><td>Footwear</td><td>Sandals</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Variation</td><td>A1 Without scarf
A2 With scarf</td><td></td><td></td></tr>
</table>

Ensemble ref	B1 + B2	***Country***	India
Gender	Female		

Description	Shalwar(Pants) Kameez (shirt) Scarf		
Underwear	Bra Briefs	***Footwear***	Sandals

Variation	B1 Without scarf B2 With scarf		
Ensemble ref	C	***Country***	Pakistan
Gender	Male		
    			
Description	Shalwar(Pants) Kameez (shirt)		
Underwear	Male underwear Socks	***Footwear***	Athletic shoes

<table>
<tr><td>Ensemble ref</td><td>D1 + D2</td><td>Country</td><td>Pakistan</td></tr>
<tr><td>Gender</td><td>Female</td><td></td><td></td></tr>
<tr><td colspan="4">  
</td></tr>
<tr><td>Description</td><td>Shalwar(Pants)
Kameez (shirt)
Scarf</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Underwear</td><td>Bra
Briefs</td><td>Footwear</td><td>Sandals</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Variation</td><td>D1 Without scarf
D2 With scarf</td><td></td><td></td></tr>
</table>

Ensemble ref	E	***Country***	India
Gender	Male		
    			
Description	Shalwar(Pants) Kameez (shirt)		
Underwear	Male underwear Socks	***Footwear***	Athletic shoes

Ensemble ref	F1	***Country***	Pakistan
Gender	Female		





Base layer also used in ensemble L2

Abaya (loose overgarment)

Long fitted hijab (headscarf)

Description	- Base layer also used in ensemble L2 including: • Stretched cotton body • Over-shirt • Jeans - Abaya (loose overgarment) - Long fitted hijab

Underwear	Bra	***Footwear***	Athletic

	Briefs Socks		shoes	
Ensemble ref		F2	***Country***	Pakistan
Gender	Female			






Base layer also used in ensemble L2

Abaya (loose overgarment)

Short traditional hijab (headscarf)

<u>Generic instructions on how to fold the traditional hijab</u> (also valid for F3 &F4):

1) Use the head band to provide friction to enable the scarf to stay on the head
2) Place the hijab over the head asymmetrically
3) Take approximately 2.5 cm of the edge of the material and turn inside.
4) Bring both sides together under the chin and secure with a grip (hairpin)
5) Pull longer edge of the hijab, up around the head and secure with a grip on the side of the head
6) Pull the reminder of the hijab, under the chin and secure with a grip on the opposite side of the head.

Description	- Base layer also used in ensemble L2 including: • Stretched cotton body • Over-shirt • Jeans - Abaya (loose overgarment)

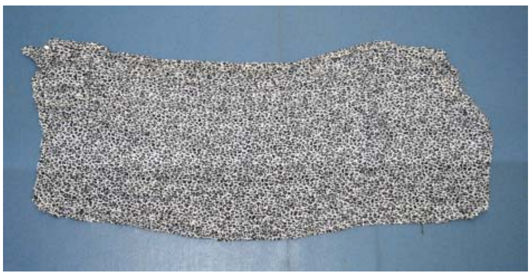
	- Short traditional hijab			
Underwear	Bra Briefs Socks	***Footwear***	Athletic shoes	
Ensemble ref		F3	***Country***	Pakistan
Gender	Female			





Base layer also used in ensemble L2

Abaya (loose overgarment)



Long traditional hijab (headscarf)

Description	- Base layer also used in ensemble L2 including: • Stretched cotton body • Over-shirt • Jeans - Abaya (loose overgarment) - Long traditional hijab

Underwear	Bra Briefs Socks	***Footwear***	Athletic shoes	

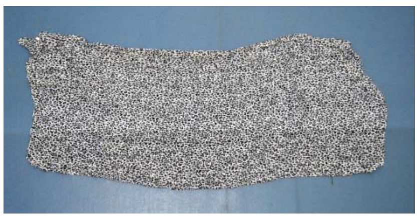
Ensemble ref		F4	***Country***	Pakistan
Gender	Female			





Base layer also used in ensemble L1 **(no cotton body)**

Abaya (loose overgarment)



Long traditional hijab (headscarf)

Description	- Base layer also used in ensemble L1 including: • Over-shirt • Jeans

<table>
<tr><td></td><td colspan="4">- Abaya (loose overgarment)
- Long traditional hijab</td></tr>
<tr><td>Underwear</td><td>Bra
Briefs
Socks</td><td>Footwear</td><td>Athletic shoes</td><td></td></tr>
<tr><td colspan="2">Ensemble ref</td><td>F5</td><td>Country</td><td>Pakistan</td></tr>
<tr><td>Gender</td><td>Female</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">   
 
Base layer also used in ensemble L2</td></tr>
<tr><td colspan="5">
Abaya (loose overgarment)

Short fitted hijab (headscarf)</td></tr>
<tr><td>Description</td><td colspan="4">- Base layer also used in ensemble L including:

• Stretched cotton body</td></tr>
</table>

<table>
<tr><td></td><td colspan="4">• Over-shirt
• Jeans

- Abaya (loose overgarment)
- Short fitted hijab</td></tr>
<tr><td>Underwear</td><td>Bra
Briefs
Socks</td><td>Footwear</td><td>Athletic shoes</td><td></td></tr>
</table>

Ensemble ref		F6	**Country**	Pakistan
Gender	Female			





Base layer also used in ensemble L2

Abaya (loose overgarment)

Short fitted hijab

Burka

Description	- Base layer also used in ensemble L2 including: • Stretched cotton body • Over-shirt • Jeans - Abaya (loose overgarment) - Short fitted hijab - Burka			
Underwear	Bra Briefs Socks	**Footwear**	Athletic shoes	

Ensemble ref	G1 + G2 + G3	***Country***	Indonesia
Gender	Female		




<u>Generic instructions on how to fold the hijab</u>:

1 2 4 4 5 5

1. Use the head band to provide friction to enable the scarf to stay on the head.
2. Fold Hijab in half to form triangle and place this over the head allowing it to fall evenly to either side, then pull one side down to make it asymetric.
3. Take approximately 2.5 cm of the edge of the material and turn inside.
4. Bring both sides together under the chin and secure with a grip
5. Pull longer edge of the hijab, up around the chin and secure with a grip on the side of the head

Description	Suit (shirt, jacket & Pants) Matching hijab (headscarf) Shirt closed to top button and tucked into Pants Jacket closed to top button		
Note	**Use shirt from Ensemble ref H**		
Underwear	Bra Briefs Socks	***Footwear***	Athletic shoes
Variation	G1 Without scarf G2 With scarf		

	G3 With scarf, no jacket		
Ensemble ref	H1 + H2	***Country***	Indonesia
Gender	Female		




<u>Generic instructions on how to fold the hijab</u>:

1 **2** **3** **4**

1) Use the head band to provide friction to enable the scarf to stay on the head.
2) Fold Hijab in half to form triangle and place this over the head allowing it to fall evenly to either side.
3) Take approximately 2.5 cm of the edge of the material and turn inside.
4) Bring both sides together under the chin and secure with a grip

Description	Student clothing consisting of: Shirt, skirt and scarf Shirt closed to top button and tucked into Pants		
Underwear	Bra Briefs Socks	***Footwear***	Athletic shoes
Variation	H1 Without scarf H2 With scarf		

Ensemble ref	I	***Country***	Indonesian
Gender	Male		



Description	Work shirt Pants Shirt closed to top button worn over Pants (**NOT tucked in**)		
Underwear	Male underwear Socks	***Footwear***	Athletic shoes

Ensemble ref	J1, J2 & J3	Country	Kuwait
Gender	Male		Winter









<u>How to wear the head set</u> :




Description	Long trouser underwear Long slevee undershirt Long serwal (Pants also used in K) Dark Dishdasha (thowb) Tagiya, Ghutra & eqa (head set) Black Coat - Scarf is worn outside the coat		Head set: A) eqal/iqal B) Tagiya C) Ghutra
Underwear	Male underwear +Socks	**Footwear**	Athletic shoes
Variation	J1 With Tagiya only		

	J2 With tagiya + iqal + ghutra J3 Same as J2 + Coat	

Ensemble ref	K1, K2 & K3	***Country***	Kuwait
Gender	Male		Summer






How to wear the head set :

See ensemble J

Description	Short sleeved t-shirt White Dishdasha (thowb), Long serwal (Pants) Tagiya, Ghutra & eqal (head set)	Head set: A) eqal/iqal B) Tagiya C) Ghutra	
Underwear	Male underwear	***Footwear***	Male sandals
Variation	K1 With tagiya only K2 With tagiya + iqal + ghutra K3: same as K2 + coat		

Ensemble ref	L1, L2 & L3	***Country***	Kuwait
Gender	Female		





Description	Stretched cotton body Over-shirt Jeans Anta (Head cover) Hijab (Head scarf) Coat		
Underwear	Bra Briefs Socks	***Footwear***	Athletic shoes
Variations	L1 without cotton body L2 with cotton body L3 with cotton body and coat		

Ensemble ref	M-S1 and M-S2	***Country***	Kuwait
Gender	Female		Summer


<u>Generic instructions on how to fold the hijab</u>:

1 **2** **3** **4**

1) Use the head band to provide friction to enable the scarf to stay on the head.
2) Fold Hijab in half to form triangle and place this over the head allowing it to fall evenly to either side.
3) Take approximately 2.5 cm of the edge of the material and turn inside.
4) Bring both sides together under the chin and secure with a grip

Description	Cotton full slip Abaya (loose overgarment) Anta (Head cover) Hijab Head scarf)		
Underwear	Bra Briefs Socks	***Footwear***	Athletic shoes
Variation	M-S1 Without head set M-S2 With head set		

Ensemble ref	M-W1 and M-W2	***Country***	Kuwait
Gender	Female		Winter

<u>Generic instructions on how to fold the hijab</u>:

See ensemble MS

Description	Long trouser underwear, Long slevee undershirt Cotton full slip Abaya (loose overgarment) Anta (Head cover) Hijab Head scarf)		
Underwear	Bra Briefs	***Footwear***	Athletic shoes

	Socks		
Variation	M-W1 Without head set M-W2 With head set		
Ensemble ref	N	***Country***	Nigeria/Ghana
Gender	Female		
    			
Description	African dress Head band		
Underwear	Bra Briefs	***Footwear***	Sandals

Ensemble ref	O	***Country***	Nigeria/Ghana
Gender	Female		
    			
Description	African long shirt African long Pants (female)		
Underwear	Bra Briefs	***Footwear***	Sandals

Ensemble ref	P	*Country*	Nigeria/Ghana
Gender	Male		




Description	African short shirt with long sleeves African long Pants (male)		
Underwear	Male underwear	***Footwear***	Male sandals

Ensemble ref	Q	**_Country_**	Nigeria/Ghana
Gender	Male		




Description	African short shirt with short sleeves African long Pants (male)		
Underwear	Male underwear	**_Footwear_**	Male sandals

Ensemble ref	R	***Country***	Nigeria/Ghana
Gender	Male		





Description	African short shirt with long sleeves African long Pants (male) Boubou (African wide sleeved robe) Matching hat

Underwear	Male underwear	***Footwear***	Male sandals

Ensemble ref	S	***Country***	Nigeria/Ghana
Gender	Female		



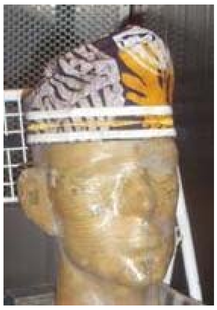


Description	African short shirt with long sleeves Long Pants (female)		
Underwear	Bra Briefs	***Footwear***	Sandals

Ensemble ref	T	**_Country_**	Nigeria/Ghana
Gender	Male		



Description	African short shirt with long sleeves African shorts		
Underwear	Male underwear	**_Footwear_**	Male sandals

Ensemble ref	U	*Country*	Nigeria/Ghana
Gender	Male		
   			
Description	African long shirt African long Pants (male) Hat		
Underwear	Male underwear	***Footwear***	Male sandals

Ensemble ref	V1, V2 & V3	***Country***	Pakistan
Gender	Male		







Description	Long trouser underwear, Long slevee undershirt Large Pants Matching long shirt		
Underwear	Male underwear+ socks	***Footwear***	Athletic shoes

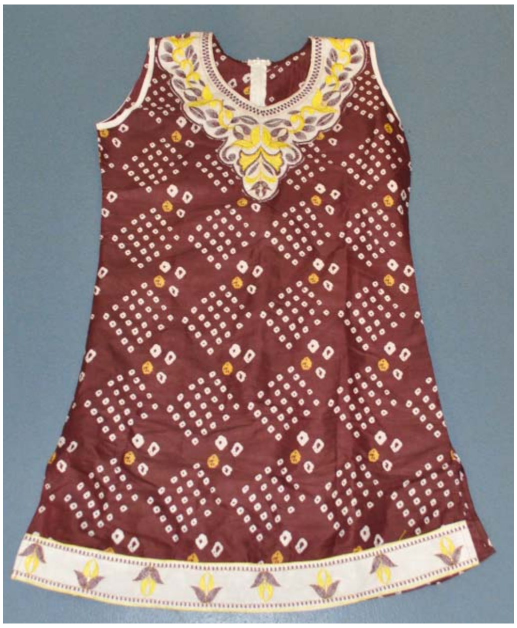
Varations	V1: no undergarment, no coat (summer) V2: with undergarment only (winter) V3: with undergarment and coat (winter)

Ensemble ref	W	**_Country_**	China (traditional)
Gender	Female		
    			
Description	Shortsleeved Qipao (body-hugging Chinese dress) Camisole (undergarment)		
Underwear	Supplied bra Briefs	**_Footwear_**	Sandals

Ensemble ref	X1	Country	India (“Churidhar”)
Gender	Female		





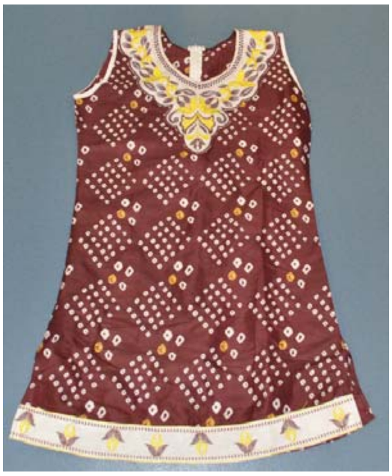


Description	Churidhar Pants Churidhar top (dress) Shawl worn as shown on photo

Underwear	Supplied bra Briefs	***Footwear***	Female sandals
Ensemble ref	X2	***Country***	India (“Churidhar” + work)
Gender	Female		






Description	Churidhar Pants Churidhar top (dress) Shawl worn as shown on photo Shirt Towel worn over the head as shown on photo		
Underwear	Supplied bra, briefs+ socks	***Footwear***	Athletic shoes

Ensemble ref	Y1	***Country***	India (Saree)
Gender	Female		






Description	Underskirt Blouse Saree (Hindu light material dress) ***<u>Instructions on how to drape a Saree</u>***:

	See next page		
Underwear	Supplied bra Briefs	***Footwear***	Female sandals


1
1. Hold inner end of the saree with your left hand.
2
2. Making sure that the saree is at floor level, tuck the top border of inner end into the Petticoat.
3
3. Then pass the Saree around to the front maintaining the same hight.
4
4. Keep the top edge level, tuck in a little to keep Saree firm.
5
5. Start folding the pleats from the right holding tuck the edge of the Saree.
6
6. Hold the pleats together and adjust the height so that bottom edge is at floor level.
7
7. Tuck inthe pleats into petticoat. The pleats should fall straight.
8
8. Bring arround the saree.
9
9. Hold it in your right and pass on to your left, arranging the border evenly.
10
10. Hold it in your right and pass on to your left, arranging the border evenly.
11
11. Hold it in your right and pass on to your left, arranging the border evenly.
12
12. Drape on your left shoulder allowing the end piece to fall casually.

Ensemble ref	Y2	Country	India (Saree + work)
Gender	Female		






Description	Underskirt Blouse Saree (Hindu light material dress) Shirt Towel worn over the head as shown on photo ***<u>Instructions on how to drape a Saree</u>***: See previous page

Underwear	Supplied bra, briefs+ socks	***Footwear***	Athletic shoes
Ensemble ref	Z	***Country***	India (Male Construction)
Gender	Male		







Description	"Banian" (vest) Pants Shirt Towel worn over the head as shown on photo		
Underwear	Male underwear (provided	***Footwear***	Athletic shoes

	with ensemble) Socks		

1504-TRP
Extension of the Clothing Insulation Database for Standard 55 and ISO 7730 to provide data for Non-Western Clothing Ensembles, including data on the effect of posture and air movement on that insulation

Report 1: Clothing Review (Progress Report)

Introduction

The aim of this project is to expand the clothing database for ASHRAE Standard 55 and IS0 9920 to include the traditional clothing of non-western countries. Clothing insulation is a crucial parameter in the assessment of thermal comfort and therefore important for the optimal design of ventilation and air conditioning systems for thermal comfort of the building occupants. Furthermore, given the growing energy needs of nations such as India, China, Pakistan, with often different clothing behavior from the west, precise knowledge of the insulation parameter is essential in optimizing energy-efficient HVAC systems for these countries.

This additional information will enable users of Standard 55, ASHRAE Fundamentals and ISO documents to make more accurate comfort predictions under realistic conditions for people clothed in non-western attire as applicable for buildings, aircraft, rail and road vehicles, and hence, with the more accurate data that will be furnished by this project, lead to more energy-efficient design.

The present report covers the starting point of the project, also leading to deliverable 1:
- Clothing review

1. Research protocol

A survey protocol was used to identify the common clothing ensembles worn in a number of the large population countries and areas; China, India, Pakistan and the Middle East. The aim was to capture an understanding of the types of clothing that people in these countries are currently wearing. This was to be achieved using a systematic survey of contacts in the target countries.

A research brief was prepared, see appendix A. The brief requested information about the type of clothing worn in offices and in light industrial work places (i.e. workplaces where the use of heating and cooling systems could be relevant) and in particular focused upon traditional clothing styles. The clothing to be considered was to be for everyday work wear rather than traditional formal ensembles which would only be worn for special occasions. Work environments that required Personal Protective Equipment were excluded as the origins of this type of equipment and clothing is predominately western (personal observations). This brief was targeted at contacts, mainly present students (Loughborough, Lund, Cornell) from the respective national areas of interest, existing research contacts in the countries themselves or alumni (Loughborough University). Apart from responding to the brief, contacts were asked where possible to take or source photographs of typical work places and outdoor activities which would present the context in which the clothing ensembles were worn. In addition, contacts were requested to cascade the request to their own contacts in the countries concerned. The results, photographs and descriptions, were fed back to Loughborough University for collation.

Country contacts and connections accessible by each consortium partner:
Loughborough University – Pakistan (via London Metropolitan University), South Korea, India, Africa, China
Lund University – Qatar, Pakistan, Nigeria, China, Lebanon
Cornell University - : China (via investigator formerly at Hong Kong Polytechnic University)

2. Results

15 responses were received, with multiple responses on the same area received for China (via Loughborough, Lund and Cornell) and for Pakistan.

The photographs from the various researchers and contacts were collated into a table for presentation purposes, see appendix B. Where images were used from internet sources, these were confirmed by the researcher/contact submitting them to be representative of the clothing associated with the region/country.

China and India were in the original project proposal considered to be of particular interest, especially given their large population numbers. It was originally thought that they may have a very high number of traditional styles of clothing that were still worn on a regular basis. However, based on individual responses received (Loughborough and Lund) and based on a focus group discussion (Cornell/Hong Kong Poly) results did not meet this expectation.

2.1 China: For office based work, particularly across China, there appears to have been a very fast transition to a whole-scale adoption of western clothing across professions and geographical locations. Males in particular have moved to a Western business suit or at very least shirt (short or long sleeved) and trousers. Denim-jeans and polo shirts/ T-shirts are worn out of work hours. Women wear blouses/shirts with trousers or skirts. Training shoes are very popular. Traditional clothing is still worn to more formal occasions and here there is a wealth of designs in these as illustrated in Fig. 1.

Figure 1 – Selection of traditional Chinese clothing ensembles.
Source - http://www.56china.com/2009/0307/993.html

2.2 India and Pakistan: Feedback received from India, indicates that there appears to have been a similar shift in the clothing worn by people in offices to that of their western counterparts. While this seems universally true for males, there still are a modest number of female workers wearing traditional clothing such as Saris and Shalwar Kameezes.

Pakistan, on the other hand, still has a much stronger link to traditional clothing, with males continuing to wear the local variations of the Shalwar Kameez. These ensembles come in summer and winter variations. Similarly, female ensembles retain a traditional element strongly based around the Shalwar Kameez.

The overall consensus of opinion of those contacted in relation to China and India is that people in these countries have essentially adopted typical western business clothing ensembles for office and light working environments.

2.3 Middle East and Africa: The middle eastern countries and Africa showed the widest range of traditional clothing ensembles that are still worn on a regular basis. However, there is also evidence of the increasing westernization of clothing in formal work places.

3. Sourcing of clothing

Clothing procurement will be undertaken by the network of researchers identified and used in the review process as well as by mail order shopping. The exact clothing ensembles have yet to be determined from the data assembled to date, but the infrastructure for acquiring clothes has been put in place.

Issues

Underwear – at this point in the study more detail is required about the under garments used and this aspect is currently being considered by the research consortium.
Sizing and fit of clothing – As various studies have looked at sizing of clothing, demonstrating the effect of fit, clothing will be sourced to fit the respective manikins. This may require up to three sizes per ensemble. However, due to unfamiliarity with the sizing system of the non-western clothing in relation to the manikin sizes, more sizes may be initially required to achieve a good fit.

Countries not considered – Japan was not considered within this review as the majority of researchers considered that the majority of the clothing worn was of western design.

4. Discussion

As the project started with a strong focus on China and India, the clothing review to date has revealed that these countries have now a much more westernized range of clothing than originally expected has caused a temporary set back in the project progress and the findings of the clothing review have thus driven the project in a slightly different direction. The first point that needs to be clarified is whether the western clothing in Chinese and Indian office settings is also similar in material type, and if not, then this implies that ensembles should be included in the project where the materials differ from their western equivalents. If the answer to this is negative, this means that the clothing selection for the project can include other countries additional to those originally considered. Information collected so far suggests that the regional clothing worn in the Middle East and Africa offers the richest variety of clothing ensembles currently being worn on a regular basis.

The extensive westernization of the clothing worn in China and India has been the surprise finding of this study so far. There are a number of opportunities which this finding affords the provides the project:

1. Traditional ensembles in countries and regions where a greater diversity of clothing still exists, (Middle East & Africa), will be explored.
2. The western style clothing worn in China and India will be evaluated to see whether there are any significant differences between the existing 'western' insulation values in the ASHRAE / ISO Standards, and those for the Chinese and Indian 'western' ensembles. This may arisebe as a result of using different materials for their manufacture. Also additional information would be gained upon the effects of posture, movement and airflow.

Due to the issues above and the practicalities of sourcing the clothing, the original plan to finalise the clothing selection and the report on this activity by month three is now considered unrealistic. In practice it appears that the clothing selection process will have to be a more iterative one (adjusted based on findings) and thus the clothing report will be built up over time during the project rather than produced in one effort in month three.

Replies to the comments and suggestions highlighted at the ASHRAE winter meeting, TC2.1 1504-TRP, January 24th 2012 are addressed and discussed in Appendix C.

Appendix A – Request for information from Research Groups

16th January 2012

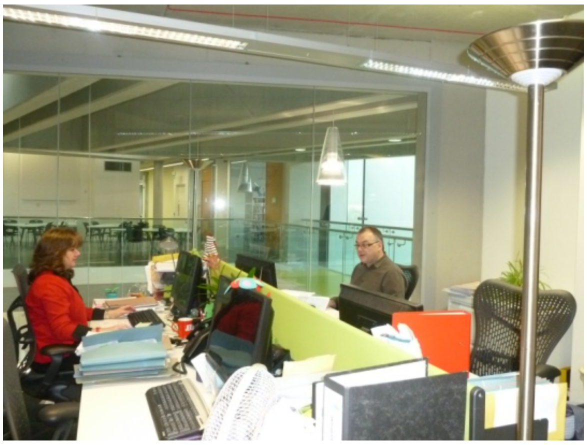
Dear Colleague

In our laboratory we are currently undertaking a project aimed at providing information on the clothing thermal insulation values for non-western clothing as used in offices, workshops, light industry and home. Clothing insulation is a crucial parameter in the assessment of thermal comfort and is therefore important for the optimal design of heating, ventilation and air conditioning (HVAC) systems for thermal comfort of building occupants. There are a number of large population areas where people often have different everyday clothing behaviour from the west, such as India, China, Middle East, etc., and better knowledge of the clothing insulation parameter for those countries will help optimize HVAC design and hence reduce carbon emissions. The outcome of this work will be used to expand clothing databases in ASHRAE Standard 55 and ISO 9920.

With this aim we are looking to gather sets of clothing ensembles which are typical of those that people would wear in these countries. Initially, we are looking for the sort of clothing that would be worn by people in homes, working in offices, shops, and light production work (but not Personal Protective Clothing).

Based on your experience of non western countries, we would like to request your help in identifying a variety of different clothing ensembles, both male and female, in each distinct geographic area that you are familiar with that could help us to form this new database of clothing.

At this stage, **we would be grateful if you could list and describe clothing that you expect people to wear in the environments mentioned above. It would be ideal if in addition you could supply photographs of people wearing the different ensembles (could be pictures from the web),** including any links you may have to local web pages where the items are sold. We would also be interested in pictures of people in workplaces and in the wider environment to help give the clothing some context. We have attached an example of the type of images we are looking for.



Leading on from that, we aim to conduct interviews and focus groups here at Loughborough with visitors from the various regions with the aim of validating the clothing selections for their suitability to the project.

Following this phase we would purchase the selected ensembles for extensive evaluation.

Any assistance in identifying and procuring these popular non western clothing ensembles would be greatly appreciated. Please email your images to Simon Hodder (s.hodder@lboro.ac.uk) as soon as possible, preferably by Monday 6th February 2012.
Any general comments regarding our request are most welcome too.

Yours sincerely
Dr Simon Hodder

Professor George Havenith
Professor Dennis Loveday
Loughborough University UK

India/Pakistan

	
Indian Saree worn in office	Salwar kameez dress
	
Indian office workers	Indian office workers
	
Indian female office worker	Indian female office worker

Saree in a Home

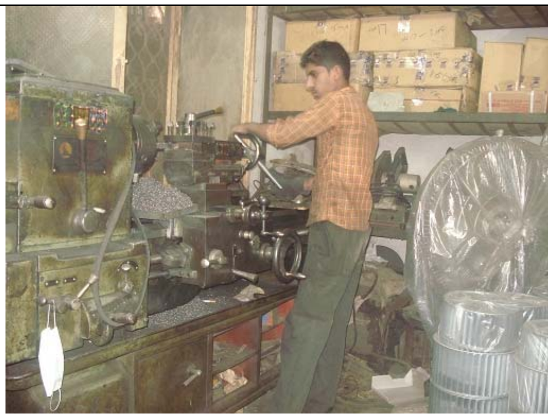
Pakistan – male summer office clothing

Pakistan – male winter office clothing

Pakistan – male winter office clothing

Pakistan – male winter office clothing

Pakistani light engineering factory

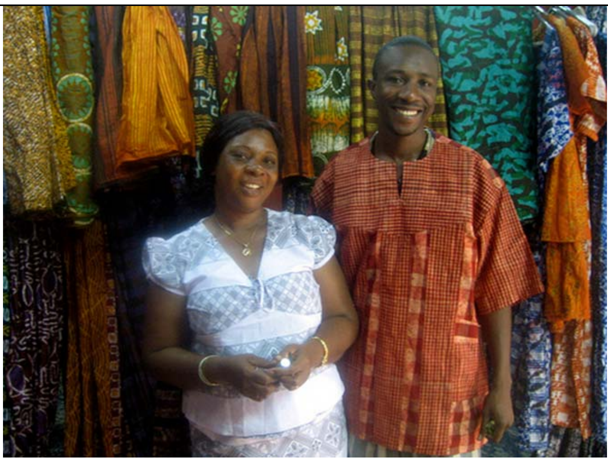
	
Pakistani light engineering factory	Pakistani light engineering factory
	
Pakistani light engineering factory	Pakistani light engineering factory
	
Pakistan – Kurta, Shalwar & shawl	Pakistan
	
Pakistan – Burka and Hijaab	Pakistan – Shalwar, Kameez & Dopart

Indonesia / China / South Korea

	
Indonesian - home	Indonesian – long dress
	
Indonesian - school	Indonesian- female office
	
Indonesian- female office	Indonesian- male office

	
Chinese office worker	Chinese male worker university
	
Chinese female office workers	Traditional chinese female
	
South Korean female workers	South Korean male office workers
	
South Korean female worker	South Korean female workers

Middle East / Africa

	
Qatar male clothing	Qatar female clothing
	
Qatar female clothing	Ghana office workers
	
Ghana – Female in Kaba &Slit – Male local print shirt	Ghanaian smock
	
Female worker – patterned dress	Office workers Ghana

	
Nigerian clothing	Nigerian clothing
	
Nigerian clothing	Nigerian clothing
	
Nigerian clothing	Nigerian clothing

	
Tunisian wedding clothing	Egytian
	
Sudanese	Algerian dress
	
Moroccan male traditional ensemble	Female winter clothing - Lebanon
	
Libyan male clothing	Kurta Shirt

	
Egyptian	Moroccain street scene
	
Moroccain street scene	Saharian /moroccain male
	
Qatar female shop worker	Qatar male office workers
	
Qatar female office workers	Chinese workers

Example fcl analysis photographic method+photoshop

Take photos at 0 and 90 degrees angle.

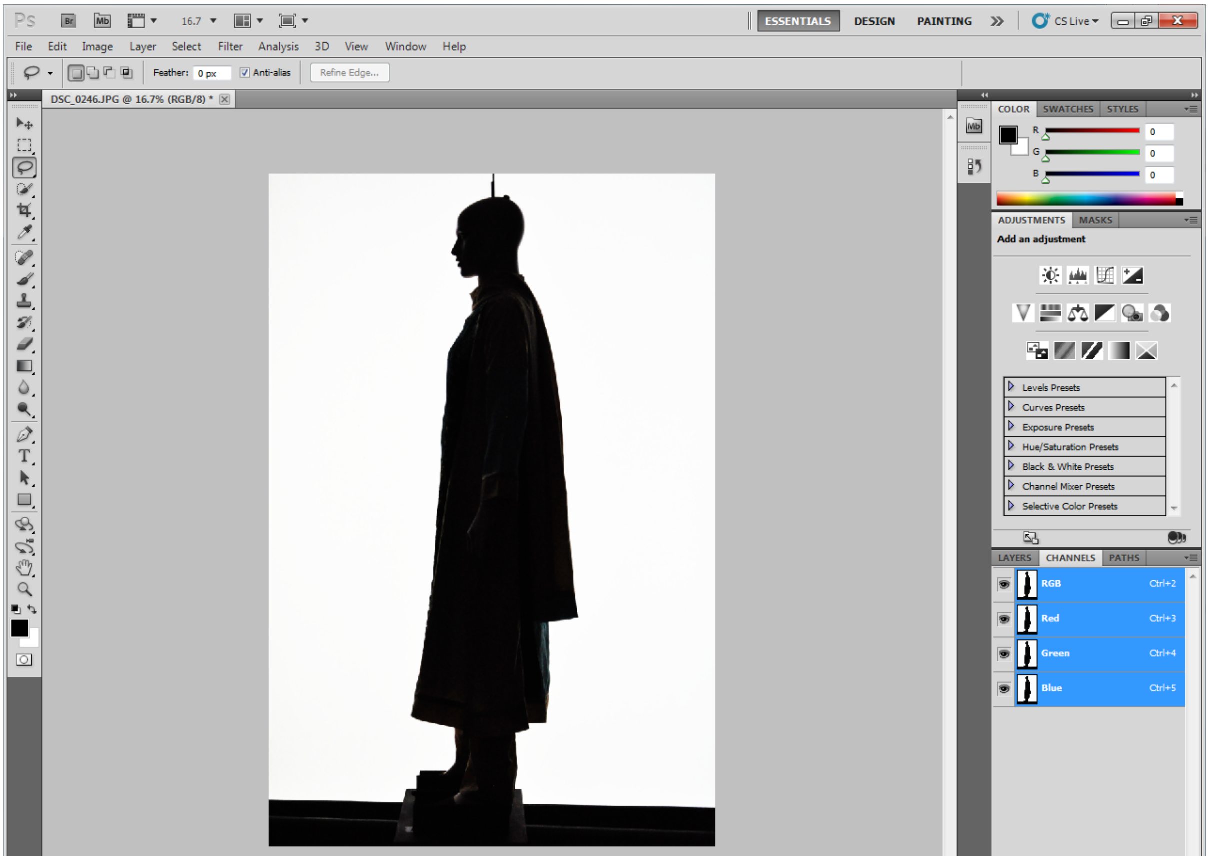
We used a backlit screen behind the manikin.

Camera should be at the height of the centre of the manikin.

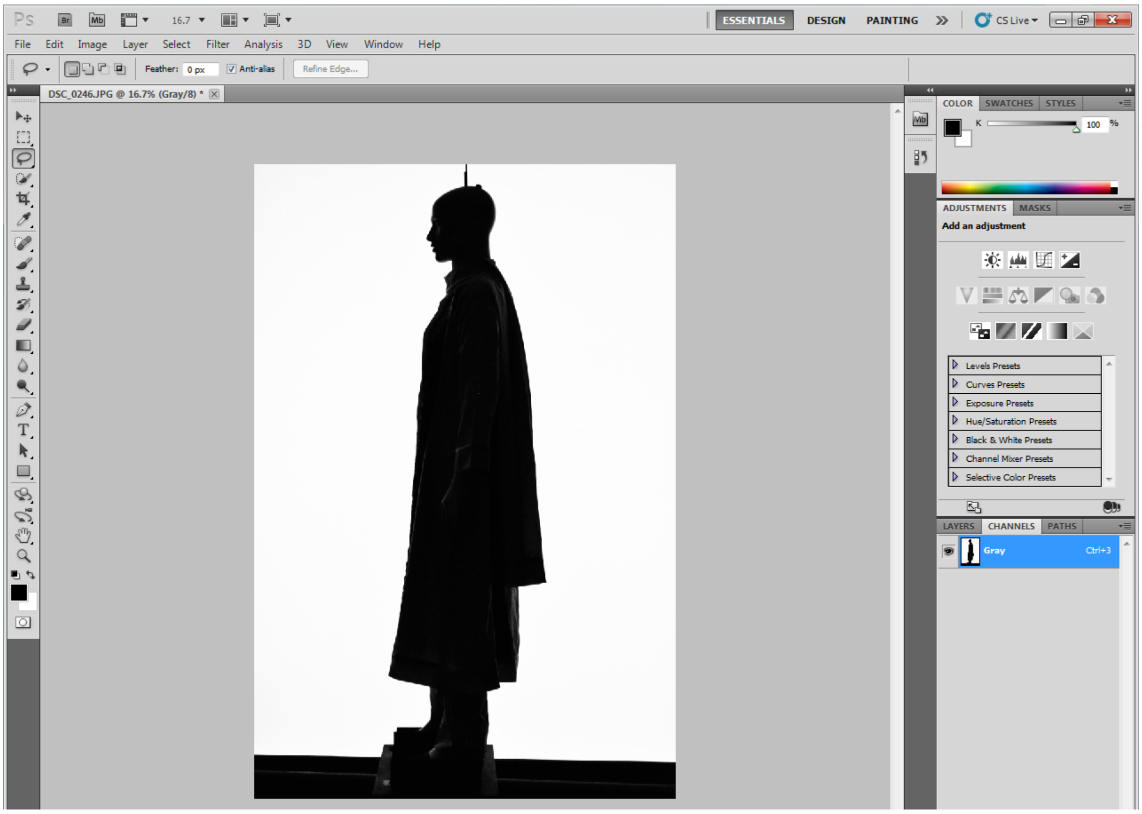
Set up for 90° angle photo

Below as example an analysis of one picture.

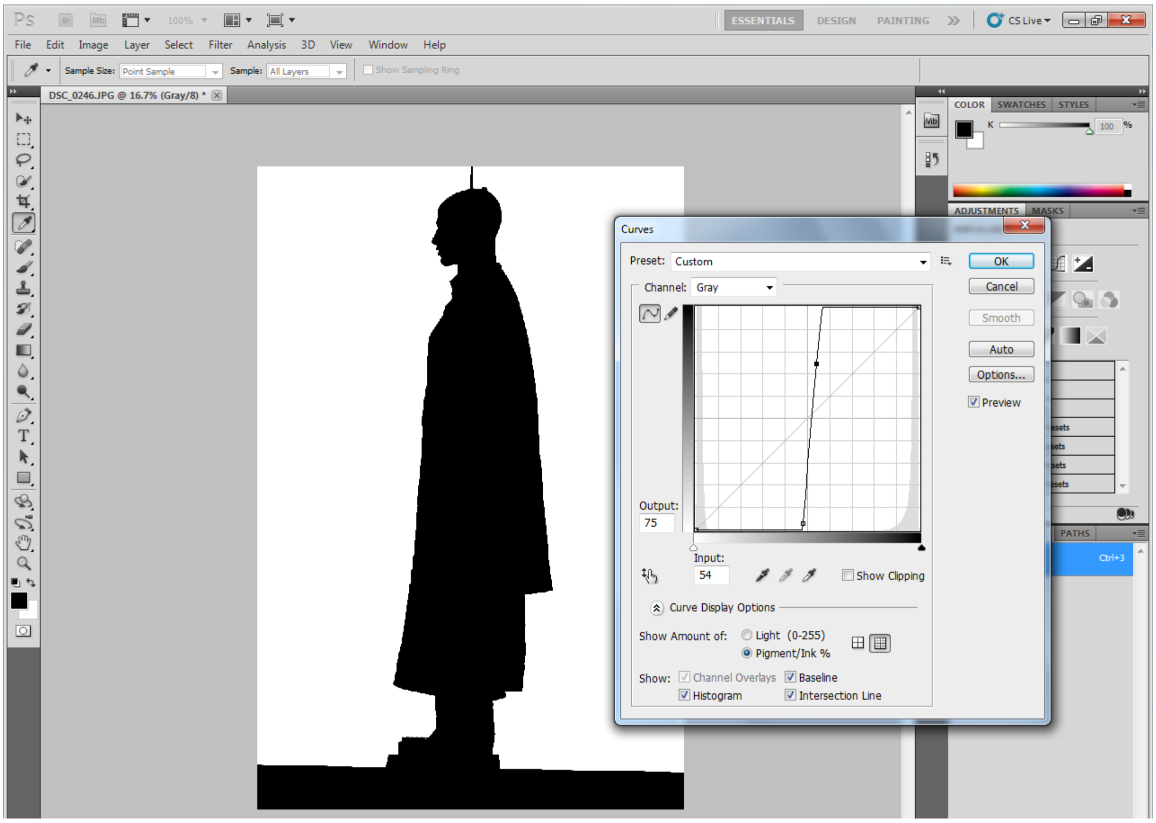
Step 1 - Upload the photo to photoshop



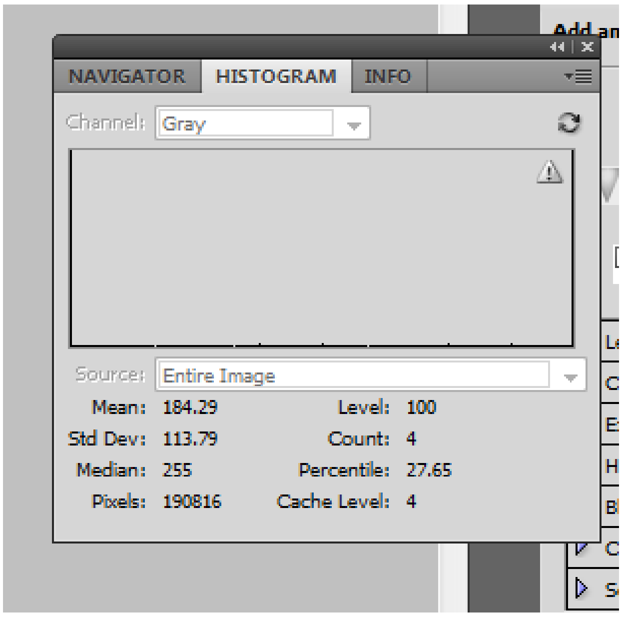
Step 2 - Click image -> adjustments -> brightness/contrast and increase both until reaching the best contrast between the manikin and background



Step 3 - Click image -> mode -> grayscale -> Discard



Step 4 - Click image -> adjustments -> Curves -> allows you to darken the dark areas and lighten the light areas. Click OK



Step 5 - Click window -> histogram. This opens the histogram box which gives you the total number of pixels in the photo and the percentile at all levels of colours between black (left end of the X-axis) and white (right end of the X-axis). We chose to record the percentile values at level 100 for all photos. If the photo has been adjusted properly (steps 1-4) then the percentile should almost not change through the whole range of greyscale levels. The numbers we are interested in are the total number of pixels and the percentile.

Before calculating the actual fcl values you will need to subtract all the extra black from the picture so only the manikin is counted. You can easily do this by cutting out the actual manikin in one picture and seeing how much black is left (floor, pedestal, rope at top).

Equation:

$$f_{cl} = \frac{[(zero\ degree\ picture\ clothed\ \text{-}\ residualblack) + (90\ degree\ picture\ clothed\ \text{-}\ residualblack)]}{[(zero\ degree\ picture\ nude\ \text{-}\ residualblack) + (90\ degree\ picture\ nude\ \text{-}\ residualblack)]}$$

We will be taking 3 photos of each garment, and between photo we will lift the clothes and allow them to re-drape.

Appendix E, air velocity distribution data

Loughborough University Air velocity data

Table E-1, Air velocity distribution Loughborough wind tunnel. Note: these detailed values were taken upon request of the steering committee. This was done AFTER all tests were done and the setup had been dismantled. Everything was put back in place to get as close as possible to the test conditions. Hence some deviation may occur from the actual test settings, which were calibrated before the test series.

No Manikin						
	set speed	height 1.7m [m/s]	height 1m [m/s]	height 0.5m [m/s]	Vane height 1m [m/s]	mean of heights
right	0.2	0.13	0.24	0.24	0.26	0.21
	SD	0.04	0.03	0.04	0.02	0.04
	0.4	0.40	0.43	0.47	0.51	0.43
	SD	0.09	0.04	0.04	0.02	0.05
	1	0.74	0.87	0.97	1.06	0.86
	SD	0.24	0.11	0.05	0.03	0.13
centre	0.2	0.21	0.20	0.24	0.19	0.22
	SD	0.04	0.04	0.03	0.03	0.04
	0.4	0.52	0.46	0.48	0.45	0.49
	SD	0.05	0.04	0.03	0.04	0.04
	1	1.17	0.98	1.04	0.85	1.07
	SD	0.09	0.08	0.05	0.10	0.07
left	0.2	0.27	0.21	0.24	0.24	0.24
	SD	0.05	0.05	0.04	0.02	0.05
	0.4	0.62	0.45	0.40	0.61	0.49
	SD	0.09	0.12	0.09	0.02	0.10
	1	1.19	1.00	0.91	1.06	1.03
	SD	0.09	0.08	0.13	0.02	0.10
						Overall means
mean of right, left, centre for each height	0.2	0.20	0.22	0.24	0.23	0.22
	SD	0.04	0.04	0.04	0.02	0.04
	0.4	0.51	0.45	0.45	0.52	0.47
	SD	0.08	0.07	0.05	0.02	0.07
	1	1.03	0.95	0.97	0.99	0.99
	SD	0.14	0.09	0.08	0.05	0.10

With Manikin						
	set speed	height 1.7m [m/s]	heigh t 1m [m/s]	height 0.5m [m/s]	Vane height 1m [m/s]	mean of heights
right	0.2	0.27	0.20	0.25	0.24	0.24
		0.05	0.05	0.05	0.02	0.05
	0.4	0.62	0.47	0.42	0.61	0.50
		0.09	0.11	0.10	0.03	0.10
	1	1.18	1.01	0.92	1.05	1.04
		0.09	0.08	0.13	0.03	0.10
centre	0.2	0.26	0.23	0.19	0.19	0.23
		0.07	0.06	0.06	0.03	0.06
	0.4	0.44	0.39	0.39	0.35	0.41
		0.06	0.04	0.04	0.02	0.05
	1	1.05	0.74	0.89	0.72	0.90
		0.07	0.04	0.04	0.02	0.05
left	0.2	0.29	0.20	0.12	0.25	0.20
		0.06	0.06	0.05	0.02	0.06
	0.4	0.51	0.39	0.38	0.39	0.43
		0.04	0.05	0.03	0.02	0.04
	1	1.12	0.89	0.77	0.83	0.92
		0.05	0.04	0.13	0.02	0.08
						Overall means
mean of right, left, centre for each height	0.2	0.27	0.21	0.18	0.23	0.22
		0.06	0.06	0.05	0.03	0.06
	0.4	0.53	0.41	0.40	0.45	0.45
		0.06	0.07	0.05	0.02	0.06
	1	1.12	0.88	0.86	0.87	0.95
		0.07	0.06	0.10	0.02	0.08

Lund University air velocity data

Air velocity was measured with Swema Air 3000d with SWA03 omnidirectional sensor (accuracy range 0.07-0.50 m/s = +-0.02 m/s, range 0.50-3.00 m/s = +-0.03 m/s) at 15 points at 40 cm in front of air velocity direction into the manikin back on Oct. 30, 2012. The points were located at 5 heights: 10 cm (30 cm from the floor), 50, 85, 125 and 160 cm from the nude manikin soles. The points were horizontally located in the center of the manikin, and 20 cm to the left and 20 cm to the right from the central line. The closest side wall was located 40 cm from the right shoulder. The recording for each point was a 3 minute average. The following values were acquired:

Table E-2, Air velocity distribution Lund; Air velocity 40 cm in front of manikin back (air flow into the back, m/s).

	Horizontal		
Vertical	20 left	Centre	20 right
160	0.20±0.08	0.33±0.10	0.30±0.10
125	0.24±0.08	0.23±0.08	0.22±0.10
85	0.22±0.07	0.19±0.06	0.19±0.07
50	0.21±0.06	0.20±0.06	0.20±0.06
10	0.29±0.05	0.26±0.05	0.22±0.05

The mean air velocity of all points was 0.23 m/s. During the tests central point at 125 cm height was checked (not with walking) and it shifted from 0.20 to 0.27 m/s as 3 minutes average for individual tests.

Air flow comes down from the perforated ceiling behind the manikin and is extracted at 0.3-0.8 m above the floor level about 1.5 m in front of the manikin, i.e. flow is somewhat diagonal.

Hong Kong Polytechnic air velocity distribution

Table E-3, Air velocity distribution Hong Kong; Air velocity information regarding the distribution around the manikin (3 levels: Head, Chest and Thigh).

	Head	Chest	Thigh
In front of the manikin (0.5m distance)	$0.39 m.s^{-1}$	$0.40 m.s^{-1}$	$0.38 m.s^{-1}$
Behind the manikin (2.0m distance):	$0.20 m.s^{-1}$	$0.18 m.s^{-1}$	$0.19 m.s^{-1}$
Left side of the manikin (0.5m distance):	$0.19 m.s^{-1}$	$0.19 m.s^{-1}$	$0.18 m.s^{-1}$
Right side of the manikin (0.5m distance):	$0.18 m.s^{-1}$	$0.19 m.s^{-1}$	$0.17 m.s^{-1}$