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Effect of Posture and Clothing on Scrotal Temperature in Fertile Men

ROGER MIEUSSET, BOURRAS BENGOUDIFA, AND LOUIS BUJAN

From the Human Fertility Research Group, Université Toulouse III – Paul Sabatier, Toulouse, France.

ABSTRACT: Investigation of the effects of body position and clothing on the temperature of the scrotum has given discordant results. The aim of the present study was to evaluate these effects in 13 fertile male volunteers in successive positions each held for 15 minutes, either Supine, Standing, Seated with legs apart, and Seated with legs crossed (n = 8) or Standing, Seated with legs crossed, and Standing (n = 5), at first naked and then clothed. The Standing naked position was that in which scrotal temperature reached the lowest point. Clothing increased the scrotal temperature compared with the naked state, whatever the position. The Seated with legs crossed position had specific characteristics: in the naked state, it was thermogenic and increased scrotal temperature as much as clothing in the Supine or Standing positions; in the clothed state, the increase in temperature was less than expected, which could indicate that local mechanisms are involved. Moreover, the Seated with legs crossed position had a persisting effect on scrotal temperature in the next position. These results have both pathophysiological and epidemiological implications.

Key words: Scrotum, testis, human, thermoregulation.
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In most mammals, including man, gametogenesis takes place in the testes at a temperature lower than that of the body (Setchell, 1998) through 2 thermoregulatory systems. The first system consists of countercurrent heat exchange (Waites and Moule, 1961) between arterial blood and the blood of the spermatic veins at the level of the cord. This heat transfer has the effect of cooling the blood arriving at the testicle. The second regulatory system consists of the scrotum, whose structural and functional properties (Waites and Moule, 1961; Shafik, 1973) enable the testicle to lose heat outside the body by passive convection and radiation. When the outside temperature rises, an active process of heat loss comes into play with evaporation of the sweat secreted by the scrotal sweat glands (Waites and Voglmayr, 1962; Candas et al, 1993). This secretion is initiated by activation of cutaneous receptors to the heat of the scrotal skin (Waites and Setchell, 1990). Scrotal temperature is thus a key element in heat regulation, since it helps to maintain testicular temperature in the physiological range required for normal spermatogenesis, both quantitatively and qualitatively (Mieusset and Bujan, 1995).

In fact, scrotal temperature may be affected by various factors, such as position, clothing, or activity (Brindley, 1982; Jung et al, 2005). Regarding position, scrotal temperature in the naked state was found to be lowest in the Standing position (Rock and Robinson, 1965; Zorgniotti and McLeod, 1973), although this was not confirmed by a recent study (Munkelwitz and Gilbert, 1998). In the Supine or the Seated position (Rock and Robinson, 1965; Zorgniotti and McLeod, 1973; Brindley, 1982; Jockenhövel et al, 1990), scrotal temperature was higher than in the Standing position. However, in the Seated position the legs may be apart, together, or crossed, and this may have a major impact on the thermal effect on the scrotum observed in the naked (Rock and Robinson, 1965) or the clothed state (Brindley, 1982; Bujan et al, 2000).

While several works have evaluated the effect of various types of underwear (Rock and Robinson, 1965; Brindley, 1982; Munkelwitz and Gilbert, 1998; Jung et al, 2005), only 1 study has really measured the effect of clothing (Zorgniotti et al, 1982). The aim of the present work was to evaluate the effect of different positions and of clothing on the scrotal temperature of fertile men.

Materials and Methods

Protocol

After the proposed experimental studies had been approved by the local Ethics Committee, all volunteers gave written informed consent to participation in the studies.

Experiment I—8 fertile (fathers of children) male volunteers (20–48 years) were included. Their histories were taken and

Correspondence to: Dr Roger Mieusset, Groupe de Recherche en Fertilité Humaine, EA 3694, Hôpital Paule de Viguier, 330, avenue de Grande-Bretagne, TSA 70034, Toulouse Cedex 9, France (e-mail: mieusset.r@chu-toulouse.fr).

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they were given a 20-minute clinical examination. Their medical, surgical, and occupational histories were unremarkable. No varicocele was found on clinical examination. Calipers were used to measure 2 dimensions of each testis, from which testicular volumes were calculated according to the formula of Lenz et al (1993). Mean testicular volumes were 25.2 mL (range: 18.8–33.1 mL) on the right and 23.8 mL (range: 18.8–30.1 mL) on the left side.

Four successive positions were held in the same room without controlled ambient temperature (22.4°–27.7°C; 8–11 AM): Supine, Standing, Seated with legs apart (at an angle of ~70°), and Seated with legs crossed (in the latter, the position of left over right or vice versa was not recorded). Each position was held for 15 minutes. All probes were placed with the men naked and standing. After 3–5 minutes acclimatization in the Supine position, recording was started for the 4 positions in the naked state. Recording was then stopped, and the men stood up and dressed within 5 minutes with normal clothing. The men then lay down and recording was resumed for the 4 positions in the clothed state.

Experiment II—5 other volunteers (25–52 years old) participated, of whom 3 were fertile and the 2 others had no personal or family reproductive history. Their histories were taken and they were given a 20-minute clinical examination. Their medical, surgical, and occupational histories were unremarkable. No varicocele was found on clinical examination. Calipers were used to measure 2 dimensions of each testis, from which testicular volumes were calculated according to the formula of Lenz et al (1993). Mean testicular volumes were 31.6 mL (range: 24.5–36.4 mL) on the right and 29.8 mL (range: 23.0–34.4 mL) on the left side.

Three successive positions were held in the same room with the temperature automatically maintained by thermostat (23.2°–23.5°C): standing (Standing Before), Seated with legs crossed, followed by standing again (Standing After). Each position was held for 15 minutes except for the second Standing position, which was held for 20 minutes. All probes were placed with the men naked and standing. After 3–5 minutes of acclimatization in a standing position, recording was started for the 3 positions in the naked state. Recording was then stopped, and the men dressed within 5 minutes in normal clothing. Recording was then resumed for the 3 positions in the clothed state.

In both Experiment I and Experiment II, temperatures were measured every 2 minutes with the model AM-7001 precision skin thermometer (accuracy of reading 0.1%, precision 0.03°C, and sensor type K; Anritsu Meter Co, Tokyo, Japan). Probes were connected to a data collector slipped into a leather case which is either hung on the trouser belt or slung from a shoulder strap. Using transparent tape (Jockenhövel et al, 1990), probes were attached to the skin at the anterior aspect of each hemiscrotum (scrotal temperatures), about 5 cm under the left breast (thoracic temperature), and, in Experiment I only, in the left axilla (axillary temperature). Body core temperature was measured using a rectal probe (Shibasaki et al, 1997) and air temperature with a special probe. Data were then transferred to statistical programs on a personal computer.

Table 1. *Scrotal temperature in the naked and the clothed state in Experiment I*[*]

	Naked		Clothed	
	Right	Left	Right	Left
Su	33.0 (0.8)[b]	32.9 (0.8)[a b]	34.3 (0.5)	34.3 (1.0)
St	32.7 (0.7)[c]	32.2 (0.9)[a c]	34.2 (0.5)	34.3 (0.9)
SLA	33.0 (0.6)[d]	32.7 (0.9)[d]	33.8 (0.6)[e]	33.9 (1.0)[f]
SLC	34.5 (0.5)[b c d]	34.3 (0.7)[b c d]	34.7 (0.3)[e]	34.7 (0.8)[f]

[*] Temperatures are given as °C; values are means ± SD; n = 8 volunteers; Su indicates Supine; St, Standing; SLA, Seated with legs apart; SLC, Seated with legs crossed; each position was held for 15 minutes; identical subscripts in the same column indicate significant differences: a: $P = .007$; b, c, d: $P < .003$; e: $P < .001$; f: $P < .004$.

In both Experiment I and Experiment II, the clothing worn (long-sleeved shirt and trousers) was of lightweight cotton. Underwear consisted of lightweight cotton boxers of similar type in all cases.

Statistical Analysis

For comparison between the naked and clothed state, as well as between positions within the same state, a mean value of the measures of each volunteer for each position was first calculated, from which the mean value and standard deviations were then computed for the 8 and 5 volunteers, respectively. The Kolmogorov-Smirnov test was used to analyze normal distribution, Wilcoxon or Student's paired t tests for means comparisons, and the Kruskal-Wallis H test for independent series. Analysis of variance with repeated measurements for each subject was used to seek explanatory factors for scrotal temperature variation. P less than .05 was taken to indicate statistical significance. Values are reported as means ± SD.

Results

Experiment I

Effect of Position in the Naked State—Rectal, thoracic and axillary temperatures did not differ significantly between the 4 positions. Mean scrotal temperatures were similar for the Supine, Standing, and Seated with legs apart positions, ranging between 32.7°C and 33°C, except for a lower mean value in the Standing than in the Supine position on the left but not on the right side (Table 1). Lastly, scrotal temperatures were significantly higher in the Seated with legs crossed position (right: 34.5° ± 0.5°C; left: 34.3° ± 0.7°C; $P < .003$) than in the other 3 positions.

Effect of Clothing—The effect of clothing was first analyzed overall by comparison of the mean value of all the measurements in the naked with the clothed state, independently of position. Ambient temperature did not differ whether the men were naked (26.0° ± 2.2°C) or clothed (25.4° ± 2.0°C). Similarly, there was no

significant difference between the naked and the clothed state for rectal (37.1° ± 0.4°C vs 37.1° ± 0.1°C) or axillary temperatures (35.7° ± 1.1°C vs 35.8° ± 1.0°C). On the contrary, thoracic temperatures were significantly higher in the clothed than in the naked state (34.0° ± 1.0°C vs 34.4° ± 0.7°C; $P < .001$). Similarly, scrotal temperatures were significantly higher in the clothed than in the naked state on the right (34.4° ± 0.5°C vs 33.3° ± 0.5°C; $P < .008$) as well as on the left side (34.7° ± 0.7°C vs 33.1° ± 0.8°C; $P < .001$).

The effect of clothing for each position was then analyzed by comparing the mean values of the temperatures in the naked and then in the clothed state. Ambient, rectal, axillary, and thoracic temperatures did not differ whether the men were naked or clothed, whatever the position (data not shown).

Scrotal temperatures (Table 1) were significantly higher (at least $P < .02$) in the clothed than in the naked state for each of the first 3 positions (Supine, Standing, or Seated with legs apart). However, for the Seated with legs crossed position, temperatures were no different between the clothed and the naked state either on the right or on the left side.

In the clothed state, scrotal temperatures (Table 1) did not significantly differ in the first 3 positions. Compared with the first 3 positions, the mean temperature of the Seated with legs crossed position was bilaterally and significantly higher only than the Seated with legs apart position.

Effect of Ambient Temperature—Ambient temperature did not vary during measurements in a single subject (no intrasubject variation) either in the naked or the clothed state. Mean ambient temperature did vary between subjects (intersubject variation), both in the naked (range: 22.4° ± 0.5°C to 27.6° ± 0.2°C; $P < .0001$) and the clothed state (range: 23.0° ± 0.5°C to 27° ± 0.2°C; $P < .0001$).

The effect on scrotal temperature of intersubject variation in ambient temperature was evaluated by analysis of variance with repeated measures for each subject, including posture (Supine, Standing, Seated with legs apart, Seated with legs crossed), state (naked, clothed), and ambient temperature. The variation of scrotal temperature was explained by posture (left: 5%; right: 9%), state (left: 37%; right: 30%), and ambient temperature for 4% and 10% on the left and right side respectively. Intersubject variation of ambient temperature thus has little effect on the observed variation of scrotal temperature.

To summarize the results of Experiment I: 1) in the naked state, scrotal temperatures in the Seated with legs crossed position significantly differed from those in the first 3 positions (Supine, Standing, or Seated with legs apart), while in the clothed state, the temperature in the Seated with legs crossed position differed significantly only from that observed in the Seated with legs apart position; 2) scrotal temperatures were significantly increased by clothing in the 3 first positions but not in the Seated with legs crossed position. Under study conditions, clothing appeared to be the preponderant factor for the first 3 positions, whereas posture was preponderant over clothing in the Seated with legs crossed position.

Table 2. *Scrotal temperature in the naked and the clothed state in Experiment II*[*]

	Naked		Clothed	
	Right	Left	Right	Left
StB	31.5 (0.3)[a b]	31.7 (0.4)[a c]	32.6 (0.2)[a b]	33.0 (0.1)[a b]
SLC	34.2 (0.8)[a c]	34.1 (0.7)[a d]	34.1 (0.6)[a]	34.2 (0.5)[a]
StA	32.5 (0.5)[b c]	32.7 (0.5)[c d]	33.9 (0.1)[b]	33.7 (0.2)[b]

[*] Temperatures are given as °C; values are means ± SD; n = 5 volunteers; StB indicates Standing Before; SLC, Seated with legs crossed; StA, Standing After; each position was held for 15 minutes except Standing After (20 minutes); identical subscripts in the same column indicate significant differences: a: $P < .008$; b: $P < .02$; c: $P < .05$; d: $P < .05$.

Experiment II

Effect of Position in the Naked State—Compared with the Standing Before position, the Seated with legs crossed position significantly increased scrotal temperatures (Table 2). In the Standing After position, scrotal temperatures significantly decreased compared with those observed in the Seated with legs crossed position. However, this decrease did not result in a return to initial values (Standing Before): in the Standing After position, scrotal temperatures remained significantly higher than those observed in Standing Before.

In summary, in the naked state, the Seated with legs crossed position not only increased scrotal temperature, but this thermogenic effect persisted during the next position.

Effect of Clothing—Comparison of the mean values of all measurements in the naked and in the clothed states showed that ambient (23.3° ± 0.3°C vs 23.3 ± 0.4°C) and rectal (37.4° ± 0.1°C vs 37.3° ± 0.1°C) temperatures did not significantly differ between the 2 states. Thoracic temperature was however significantly higher in the clothed than in the naked state (33.2° ± 0.2°C vs 34.3° ± 0.7°C; $P < .03$), as were scrotal temperatures with 33.6° ± 0.4°C vs 32.7° ± 0.5°C ($P = .04$) on the right and 33.6° ± 0.8°C vs 32.8° ± 0.7°C ($P = .06$) on the left side.

Compared with the naked state (Table 2), clothing significantly increased both right and left scrotal temperatures in the Standing Before position ($P <$

Table 3. *Baseline values of scrotal temperature at the beginning (supine position) of the naked and the clothed sessions in Experiment I*[*]

	Right scrotum	Left scrotum
Naked	32.8 (0.8)[a]	32.5 (0.8)[b]
Clothed	34.4 (0.7)[a]	34.5 (0.8)[b]

* Temperatures are given as °C; values are means ± SD; n = 8 volunteers; identical subscripts in the same column indicate significant differences: a: $P < .003$; b: $P < .008$.

Table 4. *Baseline values of scrotal temperature at the beginning (standing position) of the naked and the clothed sessions in Experiment II*[*]

	Right scrotum	Left scrotum
Naked	32.1 (1.0)	32.4 (1.0)
Clothed	32.4 (0.5)	32.8 (0.4)

* Temperatures are given as °C; values are means ± SD; n = 8 volunteers; there was no significant difference between naked and clothed values.

.008 right and left) and the Standing After position ($P < .02$ for the right side, $P < .03$ for the left). On the other hand, in the Seated with legs crossed position, left and right scrotal temperatures did not significantly differ between the naked and the clothed states: the effect of posture predominated over the effect of clothing.

In the clothed as well as in the naked state (Table 2), the Seated with legs crossed position induced a significant increase in scrotal temperature compared with the Standing Before position. But contrary to the observation in the naked state, in the clothed state the mean scrotal temperature in the Standing After position did not differ from that observed in the Seated with legs crossed position (Table 2): the thermogenic effect of the Seated with legs crossed position on the temperature of the next position (Standing After) was thus increased by the effect of clothing.

Effect of Ambient Temperature—The effect of ambient temperature on scrotal temperature was evaluated by analysis of variance with repeated measures for each subject, including posture (Standing Before, Seated with legs crossed, Standing After), state (naked, clothed), and ambient temperature. Ambient temperature had no effect on scrotal temperature.

Scrotal Temperatures at the Beginning of the Naked and Clothed Sessions

In Experiment I, the naked session ended with the Seated with legs crossed position (15 minutes); the men then dressed (5 minutes) and the clothed session began. As shown in Table 3, the means of the first measurement of scrotal temperatures at the beginning of the clothed session were significantly higher than those of the naked session.

On the other hand, in Experiment II, the naked session ended with a standing position (20 minutes) before the men dressed (5 minutes), followed by the start of the clothed session. It can be clearly seen in Table 4 that the means of the first measurement in the naked and clothed sessions were close (no significant differences) in Experiment II, contrary to what was observed in Experiment I.

Discussion

To the best of our knowledge, the present study is the first in which the same individuals have been successively studied in the naked and then the clothed state in an identical series of consecutive body positions of constant duration. Two main points emerged from the study: 1) the increase of scrotal temperatures induced by clothing, and 2) the thermogenic specificity of the Seated with legs crossed position.

Effect of Clothing

In the conditions of the present 2 experiments, clothing did not significantly influence rectal and axillary temperatures, but it increased the skin temperature of the scrotum and thorax. Clothing isolates a layer of air between skin and clothes, forming an air space under clothing the temperature of which is on average 3.5°C higher than that of the ambient air when the latter is between 21°C and 32°C, in lightly clothed, resting men (Elebute, 1976). Conditions were similar in our study. This increase in temperature of the air space under clothing as well as reduced air exchange are responsible for the rise in skin temperature. Compared with the naked state, clothing increased scrotal temperatures by 1.5°C to 2.0°C in the Supine or Standing positions, values close to the previously reported increase (1.5°C) due to clothing (Zorgniotti et al, 1982).

Thermogenic Specificity of the Seated with Legs Crossed Position

As regards the 2 Seated positions evaluated in Experiment I, they had a very different influence on scrotal temperature.

In the naked state, positioning of the legs at an angle of ~70° (Seated with legs apart) resulted in a scrotal temperature similar to that of the Supine position; on the other hand, crossing the legs (Seated with crossed legs) appeared to have a specific effect. Compared with the 3 other positions, the Seated with legs crossed position resulted in a marked and significant increase (1.4°C–2.1°C) of scrotal temperature, without any

significant effect on the axillary, thoracic, or rectal temperatures. A similar observation was made in Experiment II, in which scrotal temperatures showed a 2.4°C–2.7°C increase from the Standing to the Seated with legs crossed position.

First conclusion—In the naked state, the Seated with legs crossed position induced a thermal change that was purely local and affected the scrotum. This increase may be explained by 1) reduction of the interface between the scrotum and the external environment: exposure of the scrotal skin to the ambient air (convection) is reduced to its smallest extent by the location of the scrotum lying between the thighs in the Seated with legs crossed position; 2) by a change in the nature of the interface between the scrotum and the external environment: in this position, most of the surface of the scrotal skin is in contact (conduction) with the thighs, whose skin temperature is close to that of the scrotum, and the heat difference between the two is thus reduced. The end result is an increase in scrotal temperature.

In the naked state, the Seated with legs crossed position was associated with an increase in scrotal temperature of 1.4°C–2.1°C in Experiment I and 2.4°C–2.7°C in Experiment II compared with the previous positions, indicating that this position had a marked thermal effect on the scrotum. In the clothed state, the scrotal temperature increase in the Seated with legs crossed position was less intense than in the naked state, with 0.4°C–0.9°C in Experiment I and 1.2°C–1.5°C in Experiment II. As clothing induces a marked elevation of skin temperature, we could have expected a very marked increase in scrotal temperature in the Seated with legs crossed position in the clothed state, due to the cumulative effect of position and clothing on temperature.

The absence of this cumulative effect could reflect the triggering of mechanisms whose function is to limit the increase of scrotal temperature. Among possible mechanisms are 1) an increased surface of exchange between the scrotum and the external environment (Waites and Moule, 1961; Shafik, 1991), but this would be very limited in the Seated with legs crossed position and clothed state; 2) increased scrotal blood flow (Fowler and Setchell, 1971; Waites et al, 1973); 3) initiation of scrotal sweating and sweat evaporation (Waites and Voglmayr, 1962), although evaporative cooling would be reduced by the clothing barrier (Candas et al, 1993); and 4) increased fluid diffusion through scrotal skin (Buettner, 1969).

Second conclusion—In the clothed state, there is no cumulative effect of clothing and position in the Seated with legs crossed position. We could therefore hypothesize that in the clothed state with the Seated with legs crossed position, scrotal temperature reaches a threshold value above which some of the above-mentioned mechanisms may come into play to limit any further rise. Disturbance of these regulatory mechanisms could lead to supraphysiological increases in scrotal and testicular temperatures, with a potential impact on spermatogenesis depending on the length of time for which this position is held.

In addition to posture and clothing, variation of ambient temperature can influence scrotal temperature (Brindley, 1982). However, in the present study, inter-subject variation of ambient temperature in Experiment I had a minimal effect on scrotal temperature, of about 4% to 10%, whereas that of clothing was 30% to 37%.

Implications of the Results of Experiment II on the Results of Experiment I

In the clothed state, Experiment II shows that in the standing position (Standing After) that followed the Seated with legs crossed position, scrotal temperature did not return to the values observed in the Standing Before position, which preceded the Seated with legs crossed position. It thus appears that the Seated with legs crossed position has a persisting effect on the scrotal temperature of the next position, and that this effect is significantly more marked in the clothed than in the naked state.

In Experiment I, the naked session ended with the Seated with legs crossed position, followed by the standing position necessary for the men to dress, lasting 5 minutes. So in Experiment I, the clothed session in fact began by accumulating 2 thermogenic effects: that related to clothing and that related to the persisting effect of the Seated with legs crossed position.

Third conclusion—The Seated with legs crossed position has a persisting thermogenic effect on the next position. In the conditions of our study, this position, held for 15 minutes, had a thermogenic effect which persisted for at least 20 minutes.

In conclusion, clothing increases scrotal temperature whatever the position: Supine, Standing, Seated with legs apart, or Seated with legs crossed. Moreover, the Seated with legs crossed position has specific thermal characteristics, since 1) it appears to be the position in which scrotal temperature reaches its highest value, and 2) it has a thermogenic effect on the next position. These results have both epidemiological and physiological implications.

It seems important to make a clear distinction in epidemiological studies between the different sitting positions (legs apart, legs crossed), since these 2 positions do not act on scrotal temperature in the same way. Knowledge of the physiological variations of

scrotal temperature according to clothing and position should help to reveal abnormalities of the capacity of the scrotum to adjust to heat. These abnormalities could then be sought in clinical practice when investigating male infertility.

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