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Influence of the type of undertrousers and physical activity on scrotal temperature

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BACKGROUND: Testicular temperature correlates highly with scrotal temperature. The aim of this study was to evaluate the influence of the type of undertrousers on scrotal temperature during standardized periods of sitting and walking. METHODS: Fifty volunteers without a history of infertility and normal andrological examination were included for scrotal temperature evaluation. Temperatures were measured every minute with a portable data recorder connected with two thermistor temperature sensors, which were attached on either side of the scrotum. Ambient temperature in the study room was adjusted to 20°C throughout the whole experiment. All volunteers started the experiment at the same time of day. Clothing of the volunteers consisted of standardized cotton wool trousers and shirts fitting to body size. Each volunteer performed six periods of 45 min, either walking on a treadmill (3.0 km/h) or sitting, and wearing in a standardized and randomized manner either tight, loose fitting or no undertrousers respectively. RESULTS: The following interactions were demonstrated by means of multivariate analysis of variance for repeated measurements: scrotal temperatures were significantly higher for tight versus loose fitting versus absent undertrousers. Furthermore, significantly lower scrotal temperatures were identified for walking versus sitting as well as for the right versus the left scrotal side. CONCLUSIONS: The present study suggests that wearing tight fitting undertrousers is associated with higher scrotal and consequently testicular temperatures than wearing loose fitting undertrousers or none.

Key words: genital heat stress/physical activity/scrotal temperature/testicular temperature/type of underwear

Introduction

Testicular heat stress impairs semen quality. Spermatogenesis, especially differentiation and maturation of spermatocytes and spermatids, is temperature dependent requiring a temperature of at least 1–2°C below core body temperature (Chowdhury and Steinberger, 1970; for review: Thonneau *et al.*, 1998). This is supported by studies in humans that artificially brought testicles near or into the inguinal canal (Mieusset *et al.*, 1987; Shafik, 1991, 1992; Moeloek, 1995; Mieusset and Bujan, 1994) and induced high scrotal and consequently testicular temperatures near core body temperature. Consequently, spermatogenesis was impaired and semen quality reduced. In animals, Fukui (1923) demonstrated that suppression of spermatogenesis in experimentally induced cryptorchidism could be hindered by permanent transcutaneous cooling of the intra-abdominal testicle. Furthermore, Frankenhuis and Wensing (1979) showed that in naturally unilaterally cryptorchid pigs an intra-abdominal peritesticular cooling device could induce spermatogenesis.

Scrotal temperature is highly correlated with testicular temperature (Kurz and Goldstein, 1986; Hjollund *et al.*, 2002a). The measurement of scrotal temperature profiles under daily life conditions with the use of small temperature sensors fixed to the scrotum and connected with a portable data recorder was introduced more than 10 years ago (Jockenhövel *et al.*, 1990; Lerchl *et al.*, 1993). Thus, it became feasible to evaluate the influence of potential genital heat stress factors in a dynamic way. It is a well-established hypothesis that in andrologically healthy men (e.g. no varicocele, no hypogonadism, normal testicular size) scrotal temperature under common life conditions depends: (i) on the insulating effect of perigenital clothing and the degree of hindered air exchange; (ii) on the temperature difference between scrotal skin and the perigenital air; (iii) on the rapidity of the perigenital air exchange (passive or induced by body or leg activities); and (iv) on core body temperature (individual diurnal fluctuations) and a sufficient countercurrent heat exchange between plexus pampiniformis and testicular artery (Brindley, 1982; Setchell, 1998). However, the role of physical activity (e.g. walking versus sitting) or the type of underwear for scrotal temperature and consequently semen quality is under continuing debate. Hjollund *et al.* (2002a) found a close correlation between sedentary work position and elevated scrotal temperatures, but not between predominantly sedentary versus non-sedentary position during leisure time. Furthermore, they found no link between sedentary work position and elevated scrotal temperature or low semen quality (Hjollund *et al.*, 2002b). Interpretation of

the results obtained by Hjollund *et al.* (2002b) is hampered by the fact that classification of sitting periods during work or leisure time was achieved using a questionnaire and not connecting a movement sensor to the data recorder. The correlation of data from a questionnaire and a movement sensor may be weak (own unpublished observation). In addition, reproducibility of data from questionnaires is relatively low (Wiktorin *et al.*, 1996). Munkelwitz and Gilbert (1998) found no significant difference for scrotal temperatures in infertile men wearing tight and loose fitting undertrousers in a crossover regime. This result is in accordance with a study from Zorgniotti *et al.* (1982), who compared scrotal temperatures of men wearing tight versus loose fitting undertrousers and found no temperature differences.

The aim of our study was to re-evaluate two of the above-mentioned factors in a definitive approach under optimally standardized conditions: first, the role of the type of undertrousers, and second, the role of the activity states sitting and walking. Sitting was chosen, because under this condition perigenital air circulation and consequently perigenital heat dissipation is nearly disrupted and scrotal temperatures reach in a time-dependent manner values near core body temperature. In contrast, moderate walking on a treadmill was selected to look for a condition with excellent perigenital heat dissipation (Bujan *et al.*, 2000; Jung, 2001).

Materials and methods

Fifty volunteers [aged 18–45 years; body mass index (BMI): median 23.8 kg/m^2, range 17.6–33.4] without a history of infertility and normal andrological examination (performed according to World Health Organization, 2000) were included for scrotal temperature measurement. Median testicular volume (Prader orchidometer) was 14 ml (range: 12–20 ml). Varicoceles were excluded by palpating plexus pampiniformis during Valsalva manoeuver. Temperatures were measured every minute with a portable data recorder (AGF-Thermoport 3; Funkelektronik Gräwe, Germany; Jung *et al.*, 2003), connected to two thermistor temperature sensors (YSI Springs, USA; accuracy of measurement ±0.1°C; individual precision and reproducibility of the measurements by means of the AGF Thermoport has been reported elsewhere: Jockenhövel *et al.*, 1990), which were attached on either side of the scrotum (above the lateral surface of the testes) using Fixomull™ stretch (30 mm × 30 mm; Beiersdorf AG, Germany). A movement sensor (modified pedometer, 0–300 signals/min; Funkelektronik Gräwe, Germany) was placed proximal to the left ankle joint and connected to the AGF Thermoport. Proximal to the right ankle joint, a further pedometer (step counter; Karstadt, Germany) was fixed. This procedure was done before entering the study room. For all participants, identical equipment was used to avoid any influence caused by different measuring instruments. Ambient temperature in the study room was adjusted to 20°C throughout the experiment using a mobile air-conditioner (KY-25/Xc, cooling capacity: 2500 W; Praktiker, Germany). All volunteers started the experiment after an acclimatization period to the study room temperature of ~30 min at nearly the same daytime (13:15–13:50).

Each volunteer performed three consecutive periods each consisting of 45 min walking on a treadmill and a further 45 min sitting, while wearing in a standardized and randomized manner (to avoid the influence of diurnal temperature fluctuations) either tight fitting (jockey shorts, 100% cotton wool, Basic simply, Wal Mart), loose fitting (boxer shorts, 100% cotton wool, Mangoon, Wal Mart) or no undertrousers. In accordance with their body size, five men chose undertrousers size 5, 43 men size 6 and two men size 7. The succession for the type of undertrousers (jockey or boxer shorts or none) was determined directly after entering the study room using a die. Sixteen volunteers started the experiment wearing jockey shorts; 17 wearing boxer shorts or no undertrousers respectively. In the second part of the experiment 14 volunteers used jockey shorts; 19 boxer shorts and 17 no undertrousers. In the last part of the experiment 20 volunteers used jockey shorts; 14 boxer shorts and 16 no undertrousers. Further clothing of the volunteers consisted of standardized cotton wool trousers, and two shirts (100% cotton wool, respectively) fitting to body size. Every 45 min period of walking on a treadmill (Hanseatic 'Sport-Line 97500'; Otto-Versand, Germany) with the speed of 3.0 km/h was followed (without changing the undertrousers) by a 45 min period of sitting in a chair (right angles in the hip and the knees; legs were fixed together with a band above and under the knees in order to avoid a bias induced by changing positions of the legs).

For statistical analysis Kolmogorov–Smirnov test to clarify normal distribution and multivariate analysis of variance (ANOVA) for repeated measurements (factors: activity, scrotal side, type of undertrousers; co-factor: sequence of the type of undertrousers) were employed. Furthermore, bivariate correlations with Pearson's or Spearman's tests as well as Kruskal–Wallis test were performed. Two-sided *P*-values were calculated. $P < 0.05$ was considered statistically significant.

Approval was obtained from the Ethics Committee at the Faculty of Human Medicine, Justus Liebig University Giessen. The study period comprised March 2003 to March 2004. All volunteers gave written informed consent to participate in the study.

Results

During the three periods each of 45 min on the treadmill, volunteers walked a median distance of 2.28 km (range 2.26–2.30). The movement sensor connected to the data recorder detected median steps/min of 109.04 (range 42.96–231.78). The pedometer registered median steps/min of 82.05 (range 66.02–97.62). Figure 1 shows the pooled scrotal temperature values over the whole 45 min periods separately for the right and left scrotal sides. For statistical analysis, median values were calculated for six different exposure periods and two scrotal sides. By multiple Kolmogorov–Smirnov test, in >83% of scrotal temperature groups results were $P > 0.5$, thus normality could be assumed. Table I presents the mean values ± SD for the different exposure periods.

Right versus left scrotal side

Multivariate ANOVA demonstrated mean values of 0.1 to 0.4°C higher on the left compared to the right scrotal side ($P < 0.02$). ANOVA estimated independently of other factors a scrotal temperature mean of 35.37°C for the right and 35.56°C for the left side.

Walking versus sitting

For all types of genital clothing, ANOVA shows that during walking, scrotal temperatures were 1.5 to 2.2°C lower than during sitting for the 45 min periods on both scrotal sides

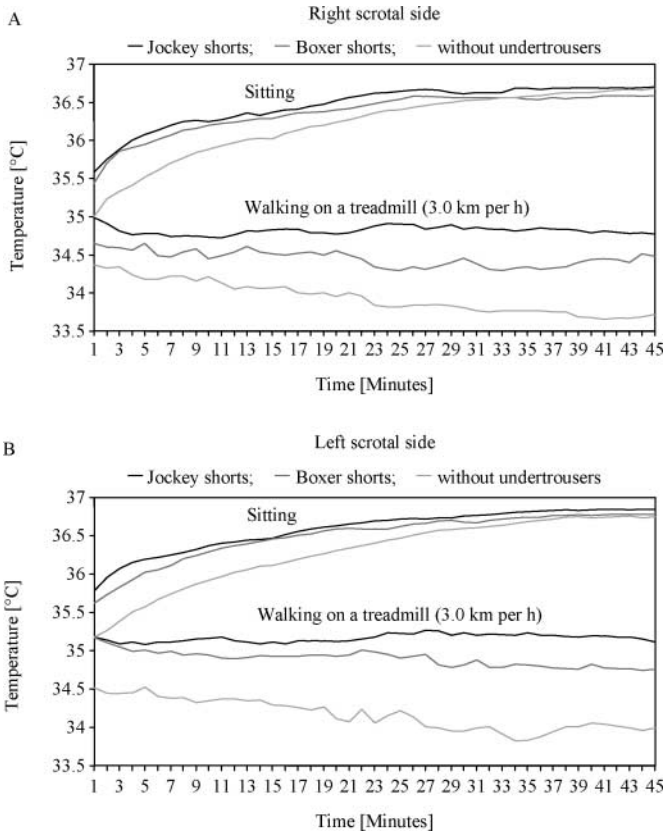

Figure 1. Influence of genital clothing during sitting and walking on scrotal temperatures in 50 healthy volunteers: (**A**) right side; (**B**) left side. Temperatures were highest wearing tight fitting undertrousers in comparison to loose fitting or no undertrousers. In contrast to sitting, differences were more pronounced during walking. Data from individuals were pooled for every minute in each period; lines shown in the figure represent respective medians. In two volunteers, the thermistors on the right scrotal side detached during study. Thus, for **A**, only complete values from 48 participants were included.

($P < 0.001$). Analysing the last 10 min of the 45 min periods, scrotal temperatures during walking were 1.6 to 2.6°C lower than during sitting. The smallest differences were found with jockey shorts and the greatest differences with wearing no undertrousers. ANOVA estimated independently of other factors a scrotal temperature mean of 36.39°C for walking and 34.54°C for sitting.

Type of undertrousers

ANOVA revealed significant scrotal temperature differences for the type of undertrousers ($P < 0.001$). During the 45 min period of walking, jockey shorts were associated with higher scrotal temperatures compared with boxer shorts [right scrotal side (rss): +0.48°C; left scrotal side (lss): +0.30°C] or no undertrousers (rss: +0.99°C; lss: +0.89°C). Moreover, wearing boxer shorts showed higher scrotal temperatures than wearing no undertrousers (rss: +0.51°C; lss: +0.59°C). The temperature differences found for the last 10 min of the walking periods were comparable with those for the whole 45 min periods. During the 45 min periods of sitting (and also the last 10 min of these periods), jockey shorts caused higher scrotal temperatures compared with boxer shorts or no undertrousers. ANOVA estimated independently of other factors a scrotal temperature mean of 35.76°C for tight fitting, 35.47°C for loose fitting, and 35.16°C for no undertrousers.

Interactions

An interaction between the type of activity and the type of undertrousers was also demonstrated by means of ANOVA ($P < 0.001$). This means that during walking the influence of the type of undertrousers on scrotal temperatures was more pronounced than during sitting. The differences of the means for the three types of undertrouser for sitting periods were only one-quarter to one-third of that for walking periods. Considering that (i) core body temperature fluctuates during the afternoon and increases over time with a possibly modulating effect on scrotal temperature and (ii) that previous activities may influence core body and subsequently scrotal temperature, scrotal temperature values were re-analysed incorporating the time sequence of wearing the undertrousers (six possible sequences) as co-factor into ANOVA. It was obvious that there were interactions between all four variables (scrotal side, activity, type of undertrousers and sequence of wearing the undertrousers) ($P < 0.05$). However, the role of the sequence of wearing the undertrousers did not reach significance alone. Moreover, it was controlled in this

Table I. Influence of type of undertrousers on scrotal temperatures in 50 healthy volunteers

Duration	Activity	Scrotal side	Scrotal temperature (°C)		
			Jockey shorts	Boxer shorts	None
45 min	Walking (3.0 km/h)	Right[a]	34.91 ± 1.11	34.43 ± 1.04	33.92 ± 1.10
		Left	35.09 ± 1.05	34.79 ± 0.96	34.20 ± 0.97
	Sitting	Right[a]	36.52 ± 0.59	36.25 ± 0.78	36.16 ± 0.86
		Left	36.58 ± 0.55	36.43 ± 0.59	36.37 ± 0.58
Last 10 min	Walking (3.0 km/h)	Right[a]	34.94 ± 1.15	34.40 ± 1.05	33.82 ± 1.13
		Left	35.14 ± 1.06	34.77 ± 0.97	34.10 ± 1.01
	Sitting	Right[a]	36.69 ± 0.52	36.42 ± 0.74	36.40 ± 0.84
		Left	36.73 ± 0.47	36.57 ± 0.58	36.62 ± 0.48

Means ± SD for scrotal temperatures calculated from the individual medians including 1 value per minute. From every 45 min period the last 10 min were additionally calculated to detect differences at the end of any period.
[a]In two volunteers, the thermistors on the right scrotal side detached during the study. Thus, for comparison only values from 48 participants were included.

study by randomized sequencing. ANOVA including this co-factor confirmed the above results.

Potential co-variants of scrotal temperature in general

For this study, the influence of season, BMI, age, and testicular size was controlled by the study design in that each participant underwent all experimental conditions with repeated measurements. However, we re-analysed the data under the assumption that such co-factors could be responsible for the great variation of scrotal temperature values in each category. The analysis of the role of season on scrotal temperatures revealed insignificant results by Kruskal–Wallis test ($P > 0.05$ in all categories). BMI was normally distributed with a mean of $23.8 \pm 3.0\,kg/m^2$. The bivariate correlation with Pearson's test revealed only one out of 12 experimental to be significant ($P < 0.05$), thus an influence of BMI on scrotal temperatures seemed unlikely. The variables age and testicular size were not normally distributed and could not be easily transformed (e.g. by a logarithm) to normality, thus we performed the bivariate correlation for these variables with Spearman's test. An influence of age was not convincing with only two out of 12 experimental categories significant ($P < 0.05$). For both testicular sizes, only four out of 12 experimental categories were significant ($P < 0.05$). This is also not a convincing result for a consistent correlation between testicular size and scrotal temperature.

Discussion

The present study provides evidence that: (i) wearing tight fitting undertrousers is associated with significantly higher scrotal and consequently testicular temperatures than wearing loose fitting undertrousers or none; (ii) walking is associated with significantly lower scrotal temperatures than sitting; (iii) scrotal temperatures were significantly higher on the left than on the right scrotal side; and (iv) the influence of insulating genital clothing is more pronounced during walking than for periods of sitting.

The results concerning the role of the type of undertrousers are in contrast to the data from other authors. Zorgniotti *et al.* (1982) compared scrotal temperatures of 24 men wearing tight fitting and 13 men wearing loose fitting undertrousers and found no temperature differences. However, they performed temperature measurements on subjects undressed and with undertrousers only 10 min apart, an inappropriate acclimatization period. Furthermore, this study did not include a cross-over measurement with the other type of undertrousers. Munkelwitz and Gilbert (1998) examined 14 subjects and found no significant temperature difference between wearing tight or loose fitting undertrousers in supine position and acclimatization to a room temperature of 24–28°C. Their methodology with measuring scrotal temperature only in the midline of the anterior scrotum using an electric digital thermometer with a low accuracy of $\pm 0.2\%$ is not satisfactory, because the necessary periscrotal manipulation for the measurement is combined with perigenital air exchange, which promptly affects scrotal temperature. Since portable data recorders and thermistor temperature sensors (Jockenhövel *et al.*, 1990) allow avoidance of such major drawbacks and performance of measurements under daily life conditions, the older scrotal skin thermometer invagination methodology should be avoided. Our study included a 2–3-fold higher number of participants for studying the influence of the type of undertrousers on scrotal temperature. Furthermore, we measured with a cross-over regimen under highly standardized conditions to avoid the influence of possible confounders such as season, BMI, age or testicular size. In addition, we performed a randomization for the sequence of the used type of undertrousers. Nevertheless, statistical analysis demonstrated that sequence was a co-factor. For future studies on this topic, it would be preferable to perform the different periods for the types of undertrousers on consecutive days during the same daytime period. However, thermistor sensors must be left attached to the scrotal skin to avoid the influence of differing attachment locations over a period of nearly 3 days. The influence of the sequence of the type of undertrousers was not simply caused by an increase in scrotal temperatures with time due to fluctuations in body temperature or by the moderate physical exercise. Our analysis demonstrates that it depends on a combination of all other factors with predominance of the type of undertrousers, physical activity, and scrotal side.

A difference of scrotal temperature between the left and right side is not known from the literature. Thus, it could be simply an artefact in our study. However, in studies with smaller numbers of participants such a minor effect could be missed, and studies with a similar or higher number of participants with temperature measurements on both scrotal sides have not yet been done. Another possible explanation would be a subclinical varicocele of the left vena testicularis. In the present study we did not perform Doppler sonography of the venae testiculares to exclude subclinical varicoceles. However, if subclinical varicoceles were the reason for higher scrotal temperatures on the left scrotal side, this should lead to a larger variation of temperature values. A putative subgroup with higher left scrotal temperatures would increase the SD. In fact, the SD for the left scrotal side in our data set were consistently lower than for the right side, so that subclinical varicoceles are not a likely explanation. A verification in future studies is necessary.

The finding that walking is associated with significantly lower scrotal temperatures than sitting is in accordance with all existing studies concerning this topic (Jockenhövel *et al.*, 1990; Lerchl *et al.*, 1993; Hjollund *et al.*, 2000, 2002a,b; Jung *et al.*, 2003). However, the effect that temperature increases due to more insulating undertrousers during walking compared to sitting are 3–4-fold higher has not been experimentally reported until now.

In several studies using portable data recorders and thermistor temperature sensors, it was demonstrated that scrotal temperatures reach values near core body temperature during night sleep (Jockenhövel *et al.*, 1990; Lerchl *et al.*, 1993; Hjollund *et al.*, 2000, 2002a,b; Jung *et al.*, 2003). During daytime, the highest values were found during sitting, and the lowest values (except undressed situations) during walking (Bujan *et al.*, 2000; Jung, 2001; Jung *et al.*, 2001a;

Hjollund *et al.*, 2002a). However, the range of temperature values in comparable situations in all of these studies was surprisingly high: Bujan *et al.* (2000) reported SD of 1.1 and 0.8°C for both scrotal sides during walking, and 0.8 and 0.5°C for sitting in a car. Jung (2001) found a SD of ~1°C for 1 h periods of sitting at a desk, walking, and sitting in a car. Hjollund *et al.* (2002a) described for 24 h profiles with night rest, day time, spare time, and working hours scrotal temperature differences between the 25 and 75% percentiles of 0.7 to 1.4°C. Despite the fact that room temperature, daytime period of the experiment, clothing (shirts, trousers and undertrousers), the sitting posture (right ankles of the hip and knees with thighs fixed together), walking conditions (3 km/h) were carefully controlled and the same thermistor sensors were used for right and left scrotal side in all volunteers, the SD of scrotal temperatures were comparable to those of the above-mentioned studies with 1.0 to 1.1°C for walking and 0.6–0.9°C for sitting. Furthermore, the influence of season, BMI, age, and testicular size of volunteers was insignificant. The argument that great variation in temperature profiles could result from temporary detachment of the thermistor or other technical problems is rather unlikely because such events would hamper the statistical evaluation leading to predominantly insignificant results. The more likely explanation for this observation would be inter-individual variation, which could not be controlled in the experiment. Considering that scrotal temperatures of monozygotic twins are well correlated in contrast to dizygotic twins or single-born brothers (Hjollund *et al.*, 2002c) our results support a genetic influence on scrotal temperature values. Nevertheless, in a future study with repeated measurements of scrotal temperatures in the same individuals under the same conditions, the distribution of values should be analysed to give further evidence for the hypothesis that scrotal temperatures depend on an intra-individual, presumably genetic factor.

Hjollund *et al.* (2002a) speculated that for semen quality the absence of cool periods is more important than the presence of hot periods. However, in therapy studies including 20 infertile men with oligoasthenoteratozoospermia due to varicocele or unknown reason (Jung *et al.*, 2001a), and further, 20 infertile men with oligozoospermia and a history of cryptorchism (Jung *et al.*, 2004), nocturnal scrotal cooling significantly improved semen quality (cooling effect of 0.8–0.9°C). Predominantly, scrotal temperatures >35°C were reduced and values <34.5°C were only moderately affected by the cooling procedure. For resolution of this discrepancy it would be necessary to evaluate in a further study with healthy volunteers the following three factors: (i) the measurement of two scrotal temperature profiles for at least representative working and weekend days; (ii) data from a movement sensor for the same periods to clearly discriminate walking periods from sitting periods; (iii) a semen analysis. Exclusion criteria for such a study should be presumably genital heat stress in the 3 months before semen analysis due to holidays in hot climate, fever (Jung *et al.*, 2001b), hot baths (MacLeod and Hotchkiss, 1941) or sauna use (Procopé, 1965).

In conclusion, the present study suggests that wearing tight fitting undertrousers is associated with higher scrotal and consequently testicular temperatures than wearing loose fitting undertrousers or none. However, it remains to be elucidated whether these differences are linked to semen quality and consequently male fertility.

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