Original Article

Evaluating the Effectiveness of a New Moisture-absorbent Vest in Preventing Heat Strain While Wearing Hospital Isolation Gowns in Climatic Chamber

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Abstract

Aim: The purpose of this study was to investigate the impact of a moisture-absorbent vest on reducing heat strain caused by the wearing of gowns by healthcare personnel. **Methods:** This experimental research was conducted on 20 healthy participants (10 men and 10 women) with a mean (SD) age of 24 ± 2 years and a body mass index of 23.65 ± 1.5 kg/m^2. Each participant underwent a 30-min workout on a treadmill in a climatic chamber at 20°C and 30°C and relative humidity of 20%–30%. Various physiological and perceptual strain indices were measured at each step. Data were analyzed using SPSS software. **Results:** The data analysis revealed that the sweat sensation scores for participants wearing normal clothes, gowns, and gowns with a moisture-absorbent vest at 30°C were 0.65, 2, and 1.49, respectively. At 20°C, the corresponding values were − 1.18, 0.62, and 0.27 (P = 0.036). In addition, there was a significant difference in skin temperature at both 30°C (P = 0.042) and 20°C (P = 0.036). Furthermore, the perceived effort showed a significant difference at 30°C (P = 0.044) and at 20°C (P = 0.002). **Conclusion:** The findings from this research suggest that the utilization of a moisture-absorbent vest did not have a significant effect on heart rate and oral temperature. However, it revealed a noteworthy impact in terms of reducing perceptual heat strain, skin temperature, perceived effort, and humidity inside the clothes.

Keywords: Gown, heat stress, moisture-absorbent vest, physiological response

Introduction

Heat stress is a significant physical factor that can have detrimental effects on the body, leading to various physiological responses. These responses typically involve increased sweating, elevated heart rate, raised core body temperature, and the establishment of heat stress equilibrium. If left unaddressed, heat stress can manifest as symptoms such as weakness, heat exhaustion, heat cramps, and even heat stroke. Additionally, heat stress has the potential to decrease productivity, contribute to human errors, and increase the risk of accidents in work environments.[1-3]

The development of heat strain is influenced by various factors that can be broadly categorized into three main categories: individual, environmental, and occupational parameters. Individual parameters include age, gender, heat adaptation, body weight, and drug use, among others, which can impact the susceptibility to heat strain. Environmental parameters such as air temperature, radiant heat, air flow, and relative humidity also play a crucial role. Occupational parameters, including working hours, job nature, workload, and the use of protective clothing, are additional factors that can contribute to heat strain.[4]

Clothing, in particular, has a significant impact on the heat exchange between the human body and the surrounding environment. Through conduction, radiation, and evaporation,

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clothing can affect the transfer of heat. Similar to insulation, clothes can act as a barrier between individuals and the environment, influencing the heat exchange processes.[5] In addition to its barrier effect, clothing also plays a crucial role in regulating body temperature by limiting the exchange of heat and moisture between the skin and the environment. The fabric, design, and sewing of clothing are important factors that influence this regulation.[6,7] Furthermore, clothing can increase the body's metabolism during physical activity.[8]

During physical activity, the human body generates heat production ranging from 70 to 110 watts while at rest. This amount significantly increases during physical exertion, and approximately 70 percent of the metabolic energy is dissipated as heat to the environment. When individuals wear protective clothing, this excessive heat load can reduce movement efficiency and significantly increase the metabolic rate required for the activity.[9]

Protective clothing is commonly utilized in various occupations, such as combat wears, nuclear, biological, and chemical suits, firefighters' suits, as well as isolation suits or gowns worn by nurses and physicians to prevent the transmission of pathogens. These garments serve to provide protection and prevent exposure in hazardous environments. The low permeability of these protective garments can lead to discomfort and an unpleasant feeling for individuals.[10] With the COVID-19 outbreak, there has a significant increase in the use of isolation gowns, resulting in discomfort and heat strain for healthcare personnel. Coca *et al*. revealed that prolonged use of isolation clothing can be exhausting for healthcare workers and can exacerbate heat stress.[11] To address these issues, the aim of this study was evaluation of the performance a moisture-absorbent vest that can be worn under isolation clothing. It is hypothesized that the combined use of isolation clothing and a moisture-absorbent vest can reduce heat stress and heat discomfort.

Materials and Methods

This experimental research was conducted in a climatic chamber. The climatic chamber was carefully controlled to maintain two distinct temperature conditions (30°C or 20°C and 20%–30%). For this study, a total of 20 individuals participated, including 10 healthy men and 10 healthy women. The participants had an average age of 24 ± 2 years, a height of 169 ± 0.35 cm, a weight of 67.55 ± 3.1 kg, and a BMI of 23.65 ± 1.5 kg/m^2. Nonprobability convenient sampling was used to select the participants.

To be eligible for the study, participants needed to meet certain inclusion criteria, such as having no infectious diseases or cardiovascular diseases, no cold symptoms, and a normal BMI. All subjects were fully informed about the procedures of the study, and written consent was obtained from each participant in accordance with the principles of the Helsinki Declaration.

Protective clothing or gowns used in this study are made of nonwoven materials with film-layer plastic. A new moisture-absorbent vests being studied consists of three layers: an inner and outer layer made of dense linen fabric and a middle layer made of a sponge material containing a water-absorbent polymer [Figure 1a].

Various parameters were measured in this study, including heart rate using a Micro life model pulse oximeter, oral temperature with a VEKTO model DT101 thermometer, and skin temperature in the region of the leg, forearm, chest, neck, and forehead using a thermometer model GP300. The relative humidity and air temperature were measured inside or outside the clothing using a TES1364 hygrometer. Thermal perceptual parameters, including sensation sweating, thermal sensation, thermal discomfort, and perceived exertion, were measured based on the scales presented in Table 1.[12]

Each participant walked on a treadmill for 30 min at a speed of 1.5 km/h and a zero incline in three stages [Figure 1b]. In the first stage, they wore cotton clothing (mode A); in the second stage, they wore a protective coverall (Gown) over the cotton clothing (mode B), and in the third stage, they wore cotton clothing, gown, and the moisture-absorbing vest (mode C). Between stages, the subjects rested for 10 min. In all stages, physiological and perceptual parameters were measured every 5 min.

To analyze the data gathered in different modes, we employed descriptive statistics such as the mean and standard deviation. In addition, we utilized the paired *t*-test to compare the parameters observed in the different intervention modes. The significance level was set at 0.05.

Results

The study aimed to investigate the effectiveness of a moisture-absorbent vest in reducing heat strain caused by wearing gowns during the COVID-19 pandemic in laboratory conditions. In the following, the effect of wearing a moisture-absorbing vest under the protective clothes (gown) on the physiological and perceptual indices is analyzed.

Thermal sensation

Thermal sensation in the A, B, and C modes were 1.9, 3.1, and 2.5, respectively, at 20°C. Comparing thermal sensation among these modes had a statistically significant (P = 0.03) when

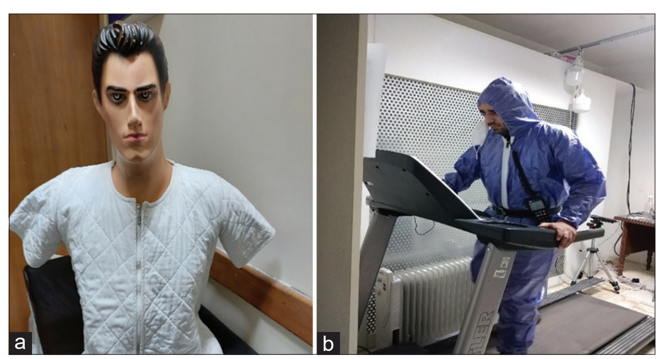

Figure 1: (a) Moisture-absorbent vest, (b) A subject during the test of the moisture-absorbent vest

the ambient air temperature increased to 30°C; the thermal sensation in the A, B, and C modes were 3.9, 5.00, and 4.3, respectively, but the thermal sensation among these modes was not statistically significant [Table 2]. Figures 2a and 3a show that the time trend of the increase in thermal sensation is highest in mode B and lowest in mode A.

Sweat sensation

At air ambient of 20°C, the sweat sensation was 0.4, 0.8, and 0.4, respectively (P< 0.001). At air ambient 30°C, sweat sensation in mode A, mode B, and mode C were 0.7, 2, and 1.5, respectively (P < 0.001). Therefore, the moisture-absorbent vest had a significant effect on the sweat sensation at both temperature conditions [Table 2]. Figures 2b and 3b show that the time trend of the increase in the sweat sensation is slow in mode A, but it is relatively high in modes B and C.

Thermal discomfort

When the air ambient temperature was set at 30°C, the thermal discomfort was 2 for mode A [Table 2], 2.9 for mode B and 2.4 for mode C (P = 0.001). Similarly, at a lower temperature of the air ambient 20°C, the average thermal discomfort for modes A, b, and C were 1.3, 1.9, and 1. 5 respectively (P < 0.001). Figures 2c and 3c show that the time trend of the increase in thermal discomfort is the lowest in mode A and the highest in mode B.

Perceived effort

At ambient air temperatures of 20°C and 30°C, the average score of perceived effort in all modes was statistically significant [Table 2]. Comparing these scores in different modes shows that in both temperature conditions, the highest value was measured in mode B and the lowest value was measured in mode A. Of course, effort perceived by the subjects' ambient air temperature 30°C is higher than in ambient air temperature 20°C, and this indicates the fact that the ambient air temperature increases the perceived effort in individuals. Figures 2d and 3d show that the time trend of the increase in perceived effort is the lowest in Mode A, but it is higher in Mode B and C compared to Mode A and they are almost similar to each other.

Air temperature inside the clothes

At ambient air temperature of 20°C, our findings revealed in different modes, the air temperature inside the garments ranged from 25.5°C to 27.0°C, and the difference between the average temperatures in the studied modes is statistically significant (P = 0.026) while at ambient air temperature 30°C, these temperature range was in the range of 31.4–32.8 and the difference between the average temperature was not statistically significant [Table 2]. Figures 2e and 3e show that the time trend of the increase in temperature inside the clothes is the lowest in mode A, but it is higher in modes B and C compared to mode C and they are almost similar to each other.

Relative humidity inside the clothes

At ambient air temperature of 20°C, the average relative humidity was 31% for mode A, 60% for Mode B, and 52% for

Table 1: Thermal feelings scales

Thermal discomfort levels		Thermal sensation levels		Sweat sensation levels		Intensity of effort levels	
Scale description	**Score**	**Scale description**	**Score**	**Scale description**	**Score**	**Scale description**	**Score**
Comfortable	1	Very cold	1	Completely dry	−3	Extremely easy	0–1
A little uncomfortable	2	Cold	2	Dry	−2	Easy	2–3
uncomfortable	3	A little cold	3	A little dry	−1	A little easy	3–4
Very uncomfortable	4	Neither hot nor cold	4	Neither wet nor dry	0	A little hard	5–6
		A little hot	5	A little wet	1	Hard	7–8
		Hot	6	wet	2	Extremely hard	9–10
		Very hot	7	Very wet	3		

Table 2: The mean and standard deviation of physiological and perceptual parameters at 20°C and 30°C in different modes (A, B and C)

Ambient temperature/ parameters	20°C				30°C			
	Mode A, mean±SD	Mode B, mean±SD	Mode C, mean±SD	*P*	Mode A, mean±SD	Mode B, mean±SD	Mode C, mean±SD	*P*
Skin temperature (°C)	36.20±0.21	36.26±0.24	36.23±0.22	0.35	36.31±0.31	36.33±0.34	36.30±0.32	0.43
Heart rate (bpm)	94.5±9.5	96.0±10.5	93.8±9.0	0.76	96.4±8.5	99.4±9.5	99.1±7.7	0.58
Thermal sensation (score)	1.9±1.6	3.0±1.7	2.5±1.8	0.03	3.9±1.4	5.0±1.5	4.3±1.6	0.10
Sweat sensation (score)	0.4±0.7	0.8±0.9	0.4±0.8	<0.001	0.7±1.7	2.0±1.3	1.5±1.5	<0.001
Thermal discomfort (score)	1.3±0.76	1.9±0.66	1.6±0.85	<0.001	2.0±0.45	2.9±0.56	2.4±0.39	0.001
Perceived effort (score)	0.8±1.9	2.0±1.7	1.7±1.8	0.002	1.6±1.1	2.8±1.3	2.7±1.0	0.044
Relative humidity inside clothes (%)	31±35	60±46	52±42	<0.001	42±26	84±16	71±35	<0.001
Air temperature inside clothes (°C)	25.6±2.6	27.0±2.9	26.8±2.7	0.026	31.4±2.5	32.9±1.9	32.8±1.8	0.16

SD: Standard deviation

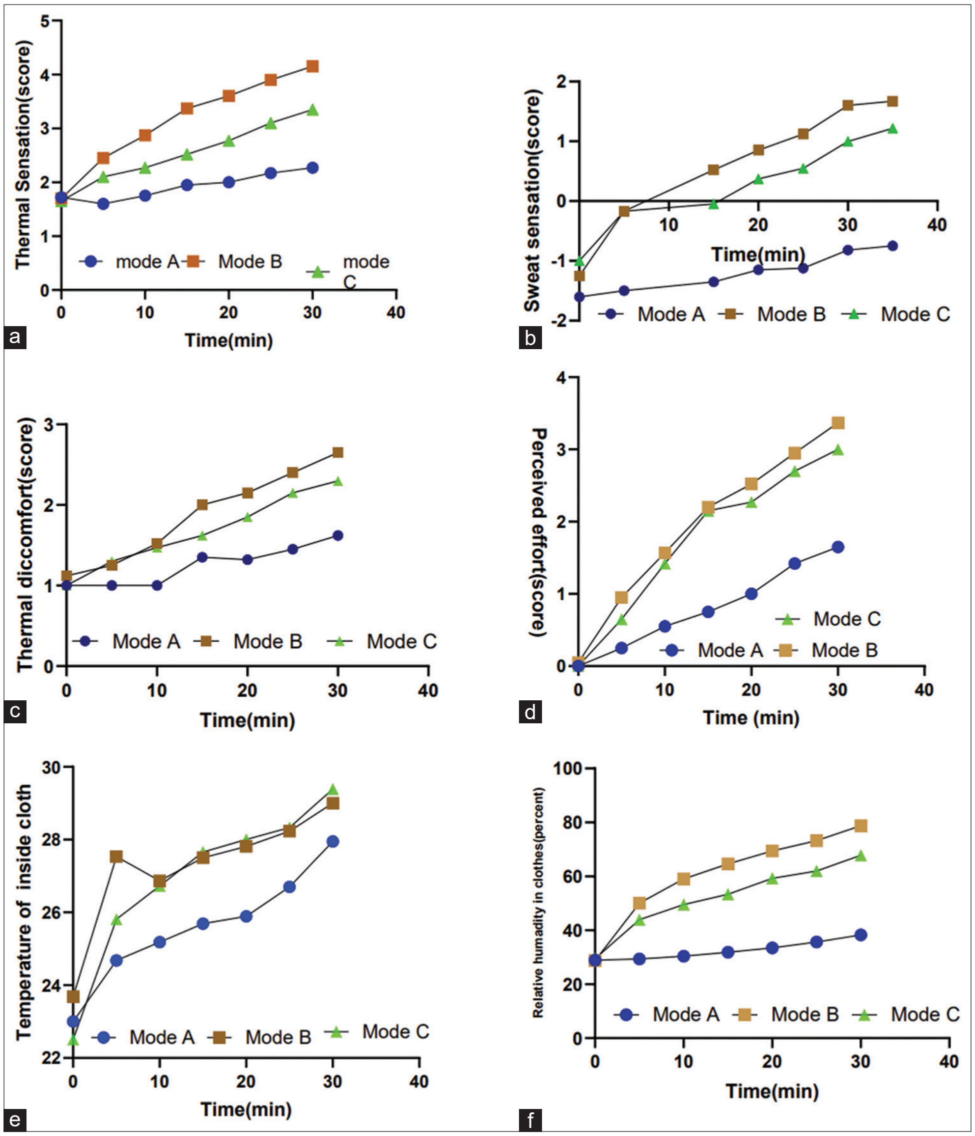

Figure 2: The trend of time changes of thermal sensation: (a) Sweating sensation, (b) Thermal discomfort, (c) Perceived effort, (d) Temperature inside clothes, (e) Relative humidity inside clothes, (f) At ambient temperature of 20°C

mode C. The difference between these values was statistically significant ($P < 0.001$). Similarly, at ambient air temperature at 30°C, the average relative humidity was 42% for mode A, 84% for mode B, and 71% for mode C. The difference between these values was statistically significant ($P < 0.001$), indicating that the moisture-absorbent vest had an impact on reducing relative humidity. Figures 2f and 3f show that the time trend of changes in relative humidity inside the clothing in mode A is approximately constant, but in modes B and C, it is higher compared to mode A and its changes are incremental.

Skin temperature

At ambient air temperatures of 20°C and 30°C, the average of skin temperature in all modes was not statistically significant [Table 2]. The difference in skin temperature in different modes at 20°C and 30°C was very small and it was close to 36°C.

Oral temperature

In our study, we found no significant difference in oral temperature between the different modes at 20°C and 30°C temperatures. At ambient air temperature of 20°C, the average oral temperature in mode A, mode B, and mode C were 36.4°C, 36.3°C, and 36.3°C, respectively ($P = 0.24$). Similarly, at ambient air temperature of 30°C, the average oral temperature recorded in three modes were 36.5°C, 36.4°C, and 36.5°C, respectively ($P = 0.95$). These findings suggest that the use of moisture-absorbent vests does not have a significant impact on oral temperature in different modes.

Heart rate

It seems that the average heart rate at 30°C was slightly (2 bpm) higher in mode B compared to mode A, but there was no significant difference among the three modes. At 20°C, the average heart rate was lower in mode A compared to mode B,

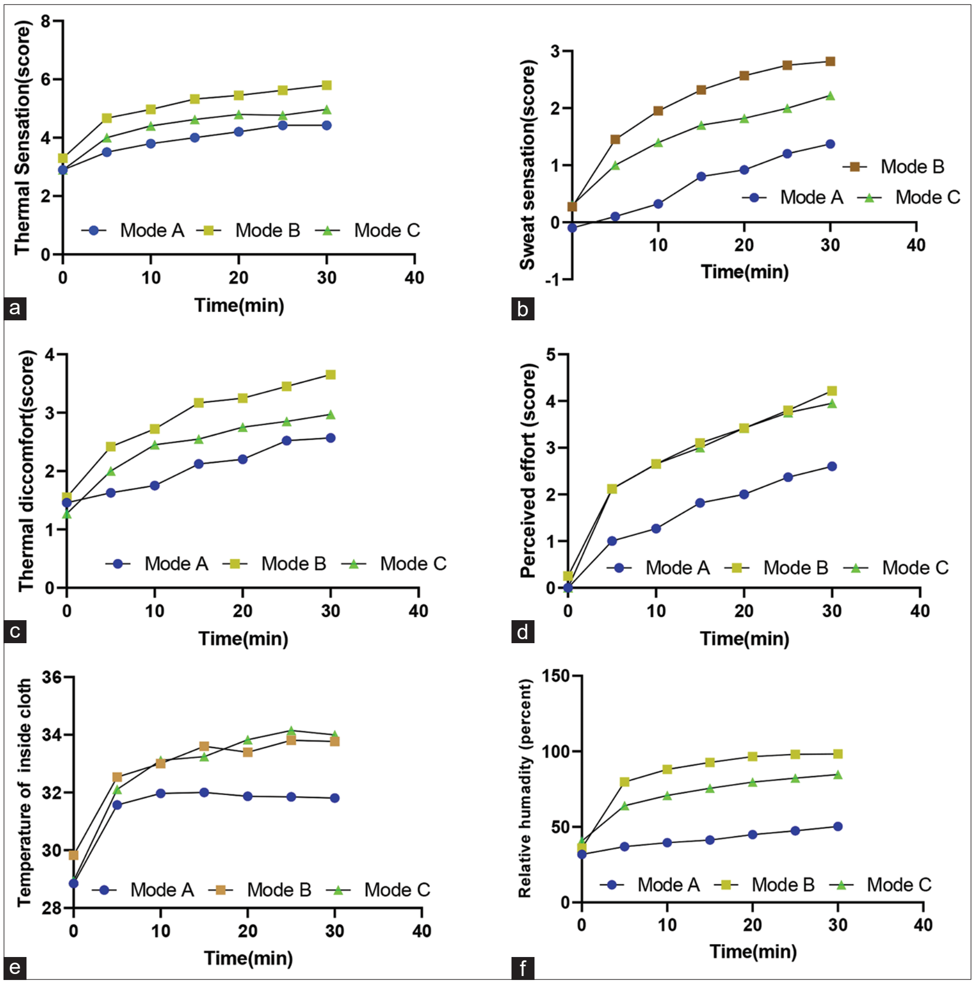

Figure 3: The trend of time changes of thermal sensation: (a) Sweating sensation, (b) Thermal discomfort, (c) Perceived effort, (d) Temperature inside clothes, (e) Relative humidity inside clothes, (f) At ambient temperature of 30°C

but again, there was no significant difference among modes A, B, and C [Table 2].

Discussion

The aim of this study was to investigate the effect of wearing a new moisture-absorbent vest on reducing heat strain caused by wearing gowns in the climatic chamber. The environmental temperatures were set as 20°C and 30°C to simulate the air-conditioning environment and the natural environment, respectively. Both subjective and physiological indices were analyzed. In order to demonstrate the benefits of moisture-absorbent vest application in terms of physiological response and psychological sensation, the whole process was monitored and statistically measured for all participants.

In this study, it was discovered that incorporating a moisture-absorbent vest beneath the gown brings about a significant decrease in various perceptual indices. In addition, the moisture-absorbent vest effectively lowers the levels of relative humidity within the garments.

According to this study findings, the use of a moisture-absorbent vest has a significant effect on the amount of sweating and perceptual sensations. Isolation clothing, made of nonwoven materials, can cause a buildup of moisture and vapor, leading to thermal discomfort. This is why the use lead to thermal discomfort due to moisture and vapor buildup. Therefore, this moisture-wicking vest can be useful due to its high moisture absorption advantage.

Nayak *et al*. showed that adding a superabsorbent material to the clothes layer of firefighters protective clothing can provide sweat absorption capacity and enhance thermal comfort. This can be beneficial for firefighters who often engage in physically demanding activities and are exposed to high temperatures.[13] Houshyar *et al*. focused on the use of moisture-absorbent vests for firefighters. They found that these vests can improve comfort while working by absorbing liquids and vapors, thus keeping the skin dry.[14] The results of these two studies are consistent with the results obtained in our study. As a result, the wearing of moisture-absorbent vests can be a reduction in sweat and an increase in overall comfort.

In this study, it was shown that at ambient temperatures of 20 and 30, wearing a moisture-wicking vest under protective clothing had no significant effect on heart rate and skin temperature.

This study also found that the use of revealed that employing a moisture-absorbent vest had not have a significant impact on heart rate and skin temperature when compared to utilizing a gown at temperatures of both 30°C and 20°C. There was no significant difference between these indices when employing a moisture-absorbent vest and versus a gown at either temperature setting. This finding is consistent with the fact that body temperature is highly positively correlated with heart rate,[15] as none of the heart rate or body temperature indices differed among different body covering states.

The study's results indicated that wearing a moisture-absorbent vest significantly reduced subject's perceived effort compared to wearing gowns alone, resulting in less fatigue. This effect was observed at both 30°C and 20°C. Previous studies have demonstrated that wearing moisture-absorbent vests or breathable fabrics that soak up body moisture can help individuals sustain intense physical activity for longer periods. Specifically, individuals wearing garments that prevent the absorption of body vapors, like gowns, are able to perform 60% less work than those wearing moisture-absorbent materials.[16]

In this study, a comparison of thermal sensation, thermal discomfort, sweating intensity and perceived activity intensity at temperatures of 20°C and 30°C shows that these indices increase significantly at 30°C, which is consistent with the results of the study by Wang *et al*.[17] They pointed out that thermal environmental factors such as air temperature, air velocity, water vapor pressure, and radiation are key factors of overall heat stress. This study emphasizes the important role of ambient temperature in increasing heat stress, perceived sensations, sweating level, and clothing temperature.

Conclusion

The findings of the current study revealed that the utilization of specially designed moisture-absorbing vests in combination with hospital isolation gowns influenced the perceptual responses such as thermal sensation, thermal discomfort and perspiration levels of the participants. While no statistically significant impact was observed on the ˡheart rate and skin temperature. This enhanced comfort and decreased sweating perception may contribute to prolonged work durations and increased overall well-being among users.

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Ethics code

IR.MUI.RESEARCH.REC.1400.020

Conflicts of interest

There are no conflicts of interest.

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