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Original Research Article

Umbrella use as a public health adaptation strategy to reduce urban heat stress exposure

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ABSTRACT

Background: Urban heat stress is a growing public health concern due to global warming. Tree planting is being promoted in urban areas as a public health heat-stress mitigation strategy. Use of personal umbrellas is considered as a low-cost, and highly adaptable alternative to trees. Several cities around the world have established programs providing umbrellas to residents. The goal of this study was to assess how the use of umbrellas compares to the effectiveness of tree shade and how such an approach can serve as a public health adaptation strategy.
Methods: The effectiveness offered by tree shade and personal umbrella shade was investigated. A field study was conducted employing wet bulb globe temperatures (WBGT) monitors, a ultraviolet (UV) radiation sensor, and a light intensity meter. Heat stress, UV radiation and visible light attenuation were measured for ten tree shades and six umbrella shades. Simultaneous measurements of both shade and direct sunlight exposure were performed to achieve controlled measurement conditions.
Results: The study showed that umbrella shade provided a reduction of visible light similar to tree shade (91% vs. 93%)/, a reduction in UV radiation (94% vs. 90%), and a reduction in WBGT heat stress (24% vs. 18%).
Conclusions: The study showed that personal umbrellas can provide protection against solar radiation in urban settings equivalent to trees and, therefore, can be used as a viable public health adaptation strategy to reduce excessive heat stress exposure in urban environments.

Keywords: Solar radiation, Urban heat stress, Umbrella shade, Public health mitigation strategy

INTRODUCTION

Urban heat stress with exposure to solar IR heat radiation and UV radiation, represents a growing public health challenge, particularly as climate change accelerates, ambient temperatures rise, and urban populations expand. Repeated and prolonged exposure to outdoor sunlight has been associated with adverse health effects such as heat exhaustion, heat stroke, dehydration, and an increased risk of skin cancer due to exposure to UV radiation.[1-3] Such risks are exacerbated by the urban heat island effect in which densely built environments experience significantly higher temperatures than surrounding rural areas. This effect is driven by reduced vegetation, the use of heat-retaining building materials, and anthropogenic heat emissions.[4-9]

A new and widely endorsed mitigation strategy is the provision of shade, either natural or artificial, to reduce heat stress exposures in urban outdoor environments. Shade can be supplied by tree canopies, awnings, built structures, or personal umbrellas. Vegetative shade, particularly from trees, has been extensively studied for its ability to lower local air and surface temperatures, alter microclimates, and enhance pedestrian thermal comfort.[10,11] In addition to temperature regulation, trees are known to contribute environmental benefits such as carbon sequestration, improved air quality, and aesthetic enhancement. However, access to tree shade is not universally available in urban areas, especially in highly developed or socioeconomically disadvantaged neighborhoods.

Personal umbrellas offer a portable, accessible form of shade that can be used independent of location or fixed infrastructure. Cities around the world are promoting the use of umbrellas to combat heat stress, particularly in densely populated urban areas and during outdoor activities.[12-15] Examples include Mumbai, India, and Kumagaya, Japan, where specialized umbrellas are distributed to primary school children to protect them from the heat. The city of Phoenix, USA, also promotes the use of umbrellas to help residents cope with high temperatures and to protect against direct sun exposure. Ahmedabad, India, installed umbrellas above streets to create shade for pedestrians during heatwaves. Seville, Spain, installed awnings and promotes the use of umbrellas. New York City, USA, initiated the "Urban Cool Umbrella" project that includes the use of “deployable shade structures” (umbrellas) throughout the city.

Limited empirical evidence based on controlled experiments exists regarding the relative effectiveness of personal umbrellas in attenuating solar radiation and reducing overall heat stress compared to tree shade.[16,17] To address this knowledge gap, the current study was designed to quantify and compare the protective effects offered by personal umbrellas in relation to tree canopies. Specifically, the investigation measured differences in visible sunlight transmission, transmission of UV radiation, and reductions in WBGT for both umbrellas and trees. The findings support existing data on the use of personal umbrellas as a viable substitute for tree shade in urban environments.[18-20] This study provides new information that can assist urban planners and public health professionals in addressing future urban heat stress challenges.

METHODS

The current research consisted of an experimental field study. Ten trees located inside a municipal park were selected for this controlled investigation. The trees selected contained a variety of canopy shapes, crown foliage and trunk heights. Each of the trees selected was separated from other trees so that no shade “overlap” occurred during a 11:30 a.m. to 1:30 p.m. measurement periods. The trees included in this study are illustrated in Figure 1. Tree shadow patterns can be seen at the base of each tree.

Six personal umbrella types were evaluated. The umbrellas had been in use previously by their owners, but none were damaged or altered. The umbrellas listed their fabric materials as 100% polyester. The umbrellas are illustrated in Figure 2.

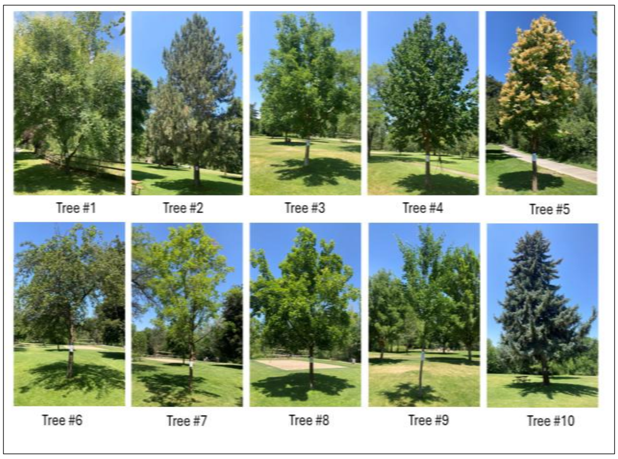

Figure 1: Tree shade conditions measured in this study.

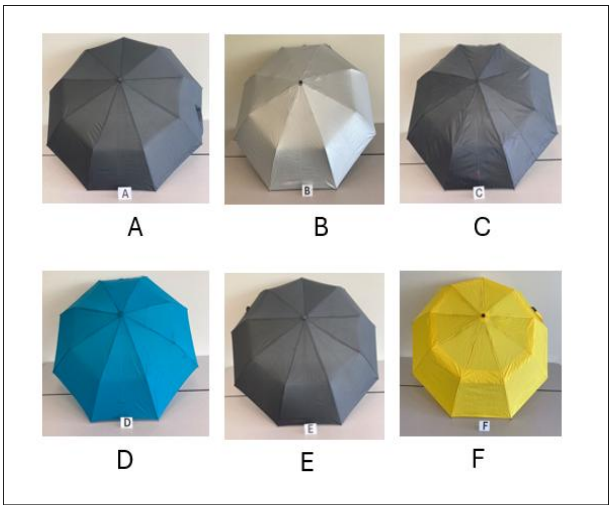

Figure 2 (A-F): Umbrella shade conditions measured in this study.

Measurement instruments used in this study included two WBGT heat stress monitors, an UV UVAB radiation monitor, and a light intensity Lux meter. While the two WBGT heat stress monitors were mounted onto tripods during the measurement periods, the UV radiation monitor, and the light intensity monitor were hand-held.

The study was conducted over a 3-day period from June 10 to June 13, 2025. Daytime air temperature, humidity, solar radiation, and wind conditions remained very similar. To minimize the influence of confounding variables, all measurements were taken between 11:30 am and 1:30 pm. During this period, air temperatures ranged from 27°C to 29°C, relative humidity levels ranged from 36% to 38%, and wind speeds ranged from 0 to 5 km/h. Skies were consistently clear, with no cloud cover.

A WBGT heat stress monitor was positioned in the shade beneath a tree. A second WBGT monitor was simultaneously placed into direct sunlight approximately 6 to 10 m away from the tree. The second WBGT monitor's exposure to direct sunlight served as a "control" for subsequent data comparison. WBGT measurements were obtained over 20-minute time periods. Instantaneous light intensity and UV radiation levels were measured at both locations, i.e., tree shade and in direct sunlight. Figure 3 shows the positioning of the monitoring instruments relative to the trees.

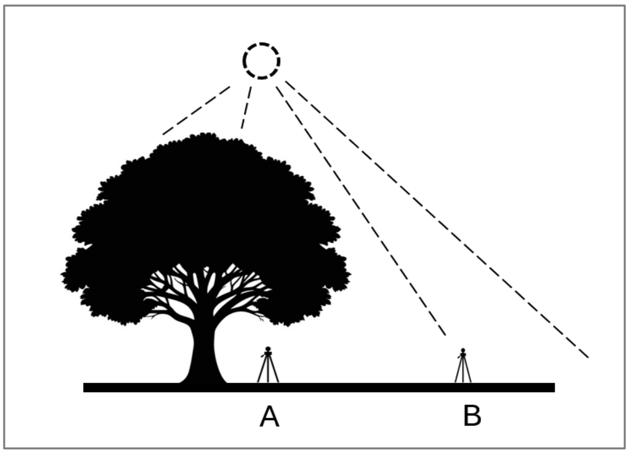

Figure 3: Illustration of instrument (A) placement under trees and (B) placement into direct sunlight (B).

Using procedures identical to those applied to the trees, one WBGT heat stress monitor was placed underneath the umbrella. A second monitor was simultaneously positioned into direct sunlight serving as the "control". Light intensity and UV radiation levels were measured simultaneously at both locations. Tree shade attenuation data and umbrella attenuation data were compared using the two-tailed T test for independent means. Figure 4 illustrates the instrument positions relative to the umbrella.

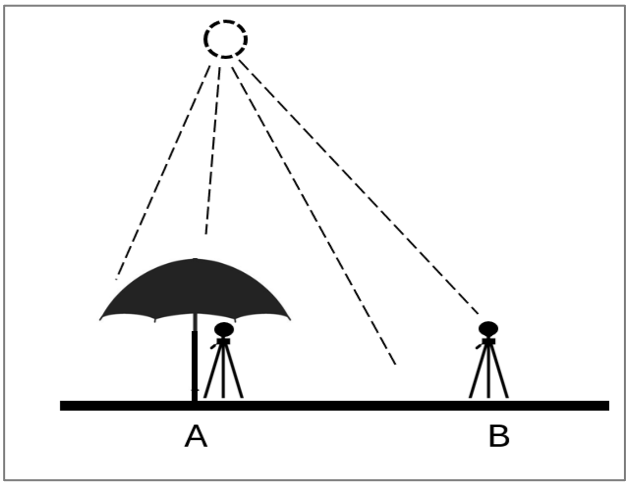

Figure 4: Illustration of instrument (A) placement under umbrellas and (B) placement into direct sunlight.

RESULTS

Table 1 summarizes values obtained for the shaded areas beneath the trees and values obtained for the direct sunlight exposure conditions. Data include light intensity levels (lux×100), UV radiation levels (mW/cm²), and WBGT values (°C). Across all trees, shaded areas exhibited lower light intensity levels (21-330 lux) compared with the sun-exposed conditions (1280-1358 lux). UV radiation was also significantly reduced in the shade, ranging from 0.23 to 2.63 mW/cm² versus 6.81 to 12.20 mW/cm² in direct sunlight. WBGT, an indicator of heat stress, was uniformly lower in the shade (17.8°C-22.3°C) than in direct sunlight (22.8°C-25.1°C).

Table 2 compares values for the umbrella shade with values obtained for direct sunlight exposure conditions. Light intensity (lux×100), UV radiation (mW/cm²), and WBGT (°C) data are presented. Direct sunlight exposure consistently resulted in higher light intensity levels (1253-1385 lux×100) compared with shaded conditions (25-305 lux×100). UV radiation was substantially reduced beneath umbrellas (0.08 mW/cm²) compared to the direct sunlight exposure conditions (approximately 13 mW/cm²). Similarly, WBGT values were consistently lower for shade (20.4°C-21.7°C) than for the direct sunlight exposure conditions (22.6°C-24.7°C).

Table 1: Summary of light intensity, UV radiation and WBGT heat stress levels observed for tree shade conditions and direct sunlight exposure.

Shade category	Visible light (Lux×100)	UV-AB (mW/cm²)	WBGT (⁰C)
Direct sunlight exposure			
(A)	1253	10.60	24.7
(B)	1260	9.87	24.2
(C)	1358	13.10	22.6
(D)	1385	13.20	23.1
(E)	1365	13.18	23.7
(F)	1320	10.89	23.1
Average	1324	11.80	23.6
Umbrella shade			
(A)	45	0.24	19.1
(B)	25	0.08	18.1
(C)	78	1.19	17.5
(D)	180	1.01	18.4
(E)	64	0.47	17.8
(F)	305	1.18	17.1
Average	116	0.70	18.0
Reduction	91%	94%	24%

The percentage reductions computed for both the trees and the umbrellas are based on proportional differences between the values obtained for the shaded areas and the "controls", i.e., exposure to direct sunlight. Light intensity levels were reduced by an average of 93%, with individual trees exhibiting reductions ranging from 75-98%. UV radiation was reduced by an average of 90%, with tree-specific values between 78% and 97%. WBGT reductions averaged 19%, ranging from 7-24%. These measurements illustrate similar protective effects offered by both umbrellas and trees. In all cases, umbrellas reduced light intensity levels ranging from 25 to 305 (Lux×100), compared to 1253 to 1385 for direct sunlight. UV radiation for umbrellas was substantially lower, ranging from 0.08-1.19 mW/cm², while direct sunlight exposure values ranged from 9.87-13.20 mW/cm². WBGT values were also lower in the shade (20.4°C to 21.7°C) than in direct sunlight (22.6°C to 24.7°C).

Table 2: Summary of light intensity, UV radiation and WBGT heat levels observed for umbrella shade conditions and direct sunlight exposure.

Shade category	Visible light (Lux×100)	UV-AB (mW/cm²)	WBGT (°C)
Direct sunlight exposure			
(1)	1280	11.40	24.2
(2)	1315	12.02	25.0
(3)	1358	11.71	23.9
(4)	1335	6.81	25.1
(5)	1320	12.20	24.2
(6)	1303	11.64	23.3
(7)	1282	11.42	23.2
(8)	1327	11.88	23.6
(9)	1341	11.96	22.8
(10)	1340	12.11	23.8
Average	1320	11.32	23.9
Tree shade			
(1)	21	0.23	19.4
(2)	46	1.02	20.2
(3)	66	1.12	22.3
(4)	43	0.81	21.2
(5)	68	1.40	18.3
(6)	330	0.93	17.8
(7)	93	1.74	18.1
(8)	37	0.71	17.9
(9)	203	2.63	20.1
(10)	39	0.59	19.4
Average	94.6	1.12	19.5
Reduction	93%	90%	18%

Table 3: Comparative summary of percent reductions of visible light, UV radiation and WBGT heat stress levels provided by tree shade and umbrella shade.

Shade category	Visible light (Lux)	UV-AB (mW/cm²)	WBGT (°C)
	Reduction	**Reduction**	**Reduction**
Trees	93%	90%	18%
Umbrellas	91%	94%	24%

DISCUSSION

The results of this study clearly show that tree shade and umbrella shade deliver strikingly similar reductions in visible light, ultraviolet radiation, and WBGT heat stress as shown in Table 3. Although smaller in magnitude, the WBGT reductions are meaningful, with proven benefits for health, safety, and productivity. Interpreted within the context of environmental conditions, activity demands, and individual susceptibility, these findings show that personal umbrellas can rival the protective power of trees.[21]

This study demonstrated that personal umbrellas can provide reductions in visible light and UV radiation comparable to tree shade, with visible light attenuation exceeding 90% and UV exposure reductions of 90-94%, which aligns with previous field and spectral studies of both umbrellas and tree canopies.[18-21] Consistent with earlier research, the largest effects were observed for sunlight and UV radiation while reductions in WBGT were more modest reflecting the nature of WBGT components that include ambient air temperature, humidity, and wind conditions simultaneously.[15] Previous studies on WBGT, sunlight and UV reductions by umbrella and street-tree reported a range of approximately 1-2 °C WBGT, comparable in magnitude to the heat stress reductions observed in this study.[15,17]

Slightly greater UV and WBGT reductions under umbrellas, relative to trees, can be explained by the uniform material of the umbrella fabrics, while tree shade is influenced by leaf gaps in the crown of a tree.[19,20] Overall, the findings in this study support the growing evidence that personal umbrellas can represent an effective, low-cost, and immediately deployable public health adaptation strategy complementing urban tree planting.[4,5,7,10,11]

CONCLUSIONS

The results of this study demonstrate that personal umbrellas can provide levels of protection from IR solar heat radiation comparable to tree shade, with higher reductions in visible light and UV radiation. Consistent with previous research, the findings confirm that while tree shade and umbrella shade primarily reduce sunlight and UV intensity levels, modest reductions in WBGT are also achieved. Unlike urban trees, which require long time horizons and substantial resources to establish, personal umbrellas represent a low-cost, portable, and immediately deployable intervention that can protect individuals during urban heat events. As urban populations face increasing heat exposure under climate change, incorporating personal shade devices such as umbrellas into public health guidance can complement long-term urban greening strategies and enhance community resilience against excessive heat stress.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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