Environ Monit Assess (2008) 145:103–111
DOI 10.1007/s10661-007-0019-2

Study of summer heat exposure at the ground services operations of a main international airport in Saudi Arabia

Madbuli H. Noweir · Abdullah O. Bafail

Received: 12 April 2006 / Accepted: 30 October 2007 / Published online: 7 December 2007

Abstract Summer heat in coastal subtropical Jeddah, augmented by heat from operating ground servicing equipment in King Abdul-Aziz International Airport (KAAIA), presents a major occupational problem to ground service operators, particularly the air traffic control coordinator (ATCC), that hinders their work efficiency and induces health disorders to them. The present study was conducted to assess the magnitude of this problem and propose heat control strategy and remedial actions for the Saudi Arabian Airlines (SAUDIA). Heat parameters including air temperature (T_a), wet bulb temperature (T_w), globe temperature (T_g) and air velocity were measured around serviced planes and in other locations used by ATCC, and the WBGT and the ATCC-WBGT-TWAs were computed. Mostly all the T_a measurements, and many T_w measurements, were higher than T_a and T_w forecasted by the Presidency of Meteorology and Environment (PME) due to heat dissipated from operating vehicles and equipment in service. The measured and PME forecasted parameters have good and medium linear correlations (T_a: r^2=0.74 and T_w: r^2=0.64). The computed WBGT in the service stations around planes are considerably higher than the 25 and 27.5°C recommended TLV® for non-acclimatized and acclimatized operators. However, the computed ATCC- WBGT-TWA levels indicate that the shift-work-schedule which was recommended to be implemented by SAUDIA has successfully reduced their heat exposure to acceptable levels, except for a very few operators (6.7% exceeding WBGT-TLV® of 25°C and 2.2% exceeding TLV® of 27.5°C) for whom the shift-work schedules might be corrected to achieve safe heat exposure.

Keywords Saudi Arabia · Heat stress · Summer heat · Airport · Air traffic control coordinator

M. H. Noweir (✉) · A. O. Bafail
Industrial Engineering Department,
Faculty of Engineering King Abdul-Aziz University,
Jeddah, Kingdom of Saudi Arabia
e-mail: madbuli@yahoo.com

Introduction

Heat exposure in Jeddah work environment has been reported to present a major problem to work population due, mainly, to the naturally occurring hot climate, augmented by work (artificial) heat load (Al-Jiffry et al. 1990; Noweir et al. 1996). Similar conditions have been reported in similar coastal areas of tropical and subtropical regions in India (Srivastava et al. 2000). Air traffic ground service operators in the airports of these areas are anticipated to be exposed to these highly heat stressful conditions due, primarily, to the local climate and secondly to the heat dissipated from operating equipment.

The Saudi Arabian Airlines (SAUDIA) have been aware of the problem of stressful heat exposure among their ground operators at King Abdul-Aziz International Airport (KAAIA), particularly on summer, when the natural climate heat is at its maxima, augmented by the tremendously increased work activities of the travel peak season of summer vacation. This awareness was the drive for the present study among SAUDIA selected ground operators: the air traffic control coordinators (ATCC).

Both naturally occurring and artificial climates have been reported to cause severe and mild heat casualties, ranging from death, where the heat stress was very high, to less heat disorders, with much greater frequency (Leithead and Lind 1964; Minard 1966; MMWR 1984, 1995, 1998; Mutchler 1991; NIOSH 1986, 1993; Ramsey and Beshir 1997). Apart from any heat disorder, occupational heat exposure erodes physical capacity and hastens the onset of fatigue, which is a crucial factor in affecting qualitative production (Kielblock 2002). Work quality cannot be maintained with temptation to "cut corners" which lead to unsafe acts. However, wide interindividual variation exists with respect to heat tolerance, making it difficult to predict individual responses. Several physical and physiological characteristics are associated with excessive strain and early exhaustion during work in hot environment; examples include: medical history of heat illness, acclimatization state, age, body composition and size, aerobic fitness level, hypertension and drug use. The end result would be affecting workers' physical performance and productivity, and increasing accidents, absenteeism and early retirement.

The present study has, therefore, been conducted with the objectives of:

(a) Assessment of thermal work environment of ATCC during July, August, September, 2003.
(b) Evaluating the role of both the climatic and the work factors on the total heat load.
(c) Defining the magnitude of the problem of ATCCs' exposure as related to their safety and health, and
(d) Recommending heat control strategy and remedial actions.

Methodology

All areas used by ramp employees during traffic control (TC) functions in KAAIA were visually surveyed to select heat assessment stations that represent all TC functions from the moment of ramp employees' arrival until their departure, and their other activities, as well as their rest areas. The following representative heat measurement stations were selected:

A. For Large (L) Planes (Boeing 777, Boeing 747, model types 100,200,300 and 400; and Air Bus A300):-

   Right-Front cabin door (R-F-L), mostly in parallel with plane engines
   Left-Front cabin door (L-L)
   Right-Rear (fourth) cabin door (R-L-L), mostly in parallel with the location of subsidiary air conditioning equipment
   Inside plane

B. For Small (S) planes (Boeing 737 and Boeing MD90:*Mc Donald Douglas*).

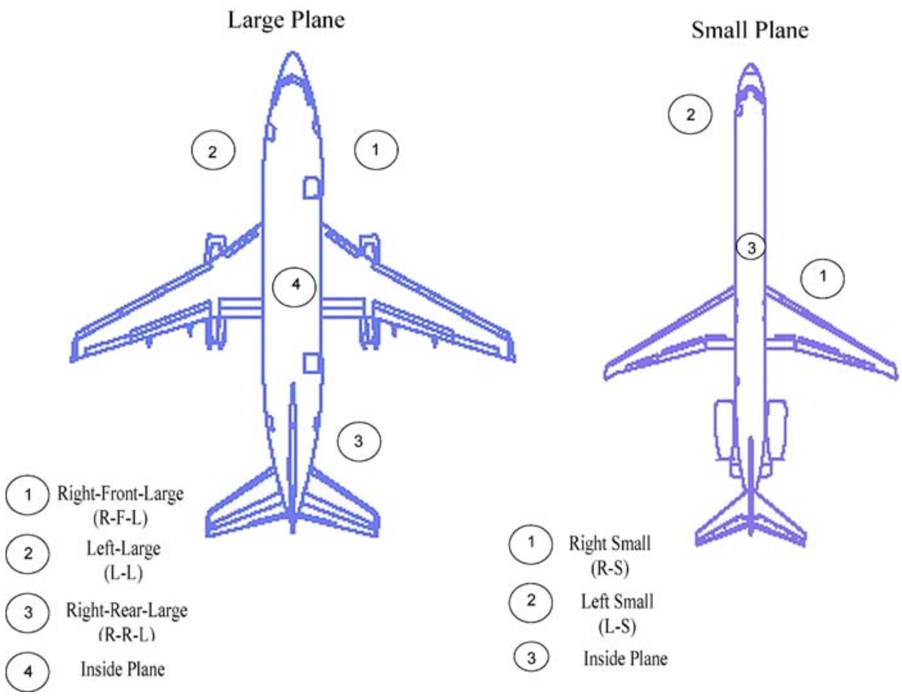
   Right cabin door (R-S)
   Left-Front cabin door (L-S)
   Inside plane

Also, heat measurements were conducted inside operators' office where they carry their administrative work. The sites of the measurement stations around both the large and the small planes are shown in Fig. 1.

Heat measurements were conducted during the period of July to September, 2003, since this period represents peak season of summer vacation travel. The measurements were made during the three work shifts [day periods comprising: morning (0600–0900 hours), forenoon (0900–1200 hours), noon (1200–1500 hours), afternoon (1500–1800 hours), evening (1800–2100 hours), night (2100–0000 hours), and midnight (0000–0600 hours)].

The measurements' data and relevant information were recorded in a specially designed and pre-tested study form (I) comprising entries for: (a) date and time of measurement, (b) description of measurement

Fig. 1 Locations of heat measurement stations



location (c) description of surrounding activities (e.g., vehicles and/or equipment and their numbers), (d) type and size of serviced plane, and (e) heat measurements which include: (1) air temperature (T_a) °C, (2) wet bulb temperature (T_w) °C; (3) globe temperature (T_g) °C; (4) wet bulb globe temperature (WBGT) °C, and (V) air velocity (m/s).

The B&K heat stress monitor type 1219 (Bruel and Kaier 1985) was used throughout the study for the measurement of the first four heat parameters, while the thermal anemometer Model 31440 of Hisamatsu (1985) was used for the measurement of air velocity.

Meanwhile, data relevant to the ATCC in charge of the work shift, during which the heat measurements were performed, were also collected and introduced into another study form (II) in order to compute the TWA exposure for each one. Data include: name and number of the operator and description of his functions in the measurement locations and time spent by him there, as well as the period of operator's existence in office. The average WBGT levels in °C was further introduced into the form as par with each function or work station, and the TWA for operator's heat exposure during the work shift was computed and recorded.

Results and discussion

The measurements of the thermal parameters (T_a, T_w, T_g, and air velocity) at the different measurement times (morning, forenoon, noon, afternoon, evening, night, and midnight) and at the different measuring locations are presented in Table 1.

The Presidency of Meteorology and Environment (PME) supplies hourly readings of climatic temperatures and wind velocity from an exposed location in the airport and has been considered as a reference for weather conditions of KAAIA. The measurements of the present study were compared with those of PME (T_a, and T_w) as regression relations and plots viz: linear, quadratic and cubic. The linear regression model represented the best relation of the measured parameters with those forecasted by PME (e g: the p values for the linear, quadratic and cubic relations have been computed for T_a to be 0, 1.14E−03, and 8.49E−02, and T_w to be 0, 1.04E−03, and 5.92E−02, respectively). Consequently, the linear relations are illustrated for T_a, and T_w in Fig. 2.

Generally, the measured ambient air temperatures (T_a: dry bulb temperatures) were higher than the PME

Table 1 Results of thermal environmental assessment of the ground flight services at KAAIA during July, August and September 2003 G

Measuring time	Measuring location	Number of measurement	Temperature (°C)				Air velocity (m/s)
			T_a	T_w	T_g	WGBT	
Morning	R-F-L	17	34.5 (3.1)	28.6 (1.4)	39.0 (4.9)	31.3 (2.0)	2.0 (1.4)
	L-L	15	33.8 (2.2)	28.5 (1.4)	37.7 (3.5)	30.8 (1.6)	2.2 (1.7)
0600–0900	R-R-L	17	34.0 (3.0)	28.7 (1.4)	38.4 (4.6)	31.1 (1.9)	2.1 (1.2)
hours	R-S	10	31.3 (3.0)	27.7 (1.3)	33.9 (4.0)	29.3 (1.8)	1.9 (0.7)
	L-S	7	31.1 (2.8)	27.9 (1.2)	34.1 (4.5)	29.4 (2.0)	1.6 (0.7)
Forenoon	R-F-L	16	38.1 (1.8)	28.9 (1.3)	43.9 (2.3)	32.8 (1.3)	3.2 (2.1)
	L-L	17	37.4 (1.4)	28.7 (1.3)	43.2 (1.9)	32.5 (1.1)	2.9 (1.5)
0900–1200	R-R-L	14	37.9 (1.6)	28.8 (1.3)	43.7 (1.8)	32.7 (1.3)	2.7 (1.1)
hours	R-S	6	37.9 (0.8)	28.7 (0.8)	44.5 (1.4)	32.8 (0.5)	3.7 (2.0)
	L-S	7	37.8 (1.2)	28.9 (1.0)	43.2 (1.8)	32.6 (0.9)	4.3 (2.4)
Noon	R-F-L	11	39.6 (1.6)	29.0 (0.9)	45.9 (2.3)	33.4 (1.0)	4.3 (2.6)
	L-L	12	38.8 (1.3)	28.4 (0.8)	44.3 (1.2)	32.6 (0.5)	5.7 (1.9)
1200–1500	R-R-L	11	38.6 (1.2)	28.7 (1.0)	44.0 (1.8)	32.7 (1.0)	4.8 (2.8)
hours	R-S	9	39.5 (0.5)	29.3 (1.6)	45.5 (1.3)	33.5 (1.3)	3.4 (1.8)
	L-S	10	39.2 (1.6)	29.0 (1.7)	45.0 (2.4)	33.2 (1.3)	4.7 (2.5)
Afternoon	R-F-L	9	39.5 (2.3)	29.6 (1.9)	45.7 (3.1)	33.8 (1.2)	3.1 (1.0)
	L-L	9	38.9 (1.3)	29.2 (2.2)	45.1 (2.2)	33.3 (1.7)	2.8(1.3)
1500–1800	R-R-L	9	39.0 (1.5)	29.8 (1.9)	44.9 (2.2)	33.8 (1.4)	1.9 (0.7)
hours	R-S	11	38.4 (1.7)	28.0 (2.2)	42.5 (2.3)	31.9 (1.3)	3.6 (1.8)
	L-S	7	37.7 (1.3)	27.9 (2.1)	42.4 (1.4)	31.8 (1.3)	4.5 (1.5)
Evening	R-F-L	13	36.3 (2.2)	28.2 (2.3)	38.4 (2.6)	31.1 (1.2)	2.2 (1.0)
	L-L	13	35.3 (1.0)	28.3 (2.2)	37.2 (0.9)	30.8 (1.5)	1.7 (0.7)
1800–2100	R-R-L	13	36.3 (1.5)	28.2 (2.6)	38.2 (1.2)	31.0 (1.8)	2.3 (1.0)
hours	R-S	5	36.5 (1.9)	27.0 (3.3)	38.4 (2.1)	30.2 (2.2)	1.8 (0.8)
	L-S	9	36.6 (1.3)	26.7 (2.8)	39.0 (2.4)	30.2 (1.9)	1.8 (1.0)
Night	R-F-L	19	34.4 (1.3)	27.4 (2.8)	36.1 (1.6)	29.8 (2.0)	2.5 (1.3)
	L-L	21	34.8 (2.6)	27.4 (2.6)	37.0 (4.4)	30.0 (2.4)	1.8 (0.8)
2100–0000	R-R-L	16	35.8 (3.6)	28.5 (3.0)	37.9 (4.2)	31.1 (3.0)	2.3 (0.9)
hours	R-S	3	33.1 (1.3)	28.5 (2.3)	34.5 (1.8)	30.2 (2.0)	2.4 (1.4)
	L-S	4	34.4 (1.5)	28.4 (1.9)	35.4 (1.7)	30.4 (1.6)	0.9 (0.5)
Midnight	R-F-L	37	30.7 (1.2)	27.0 (1.9)	32.6 (1.4)	28.5 (1.5)	1.7 (0.7)
	L-L	38	30.4 (1.0)	26.7 (1.8)	32.5 (1.2)	28.2 (1.4)	1.6 (0.8)
0000–0600	R-R-L	36	32.0 (3.4)	27.3 (2.3)	34.0 (3.6)	29.1 (2.4)	1.7 (0.7)
hours	R-S	6	29.7 (0.9)	27.3 (0.6)	31.4 (1.0)	28.4 (0.7)	1.3 (0.1)
	L-S	6	29.8 (1.3)	27.3 (0.9)	31.3 (1.1)	28.3 (0.8)	1.4 (0.5)
Integrated time	In plane	133	25.7 (2.2)	19.9 (2.4)	29.3 (2.5)	22.8 (2.1)	0.3 (0.2)
	In office	88	24.1 (1.9)	18.2 (1.8)	25.5 (1.6)	20.4 (1.7)	0.2 (0.1)

Mean (SD)

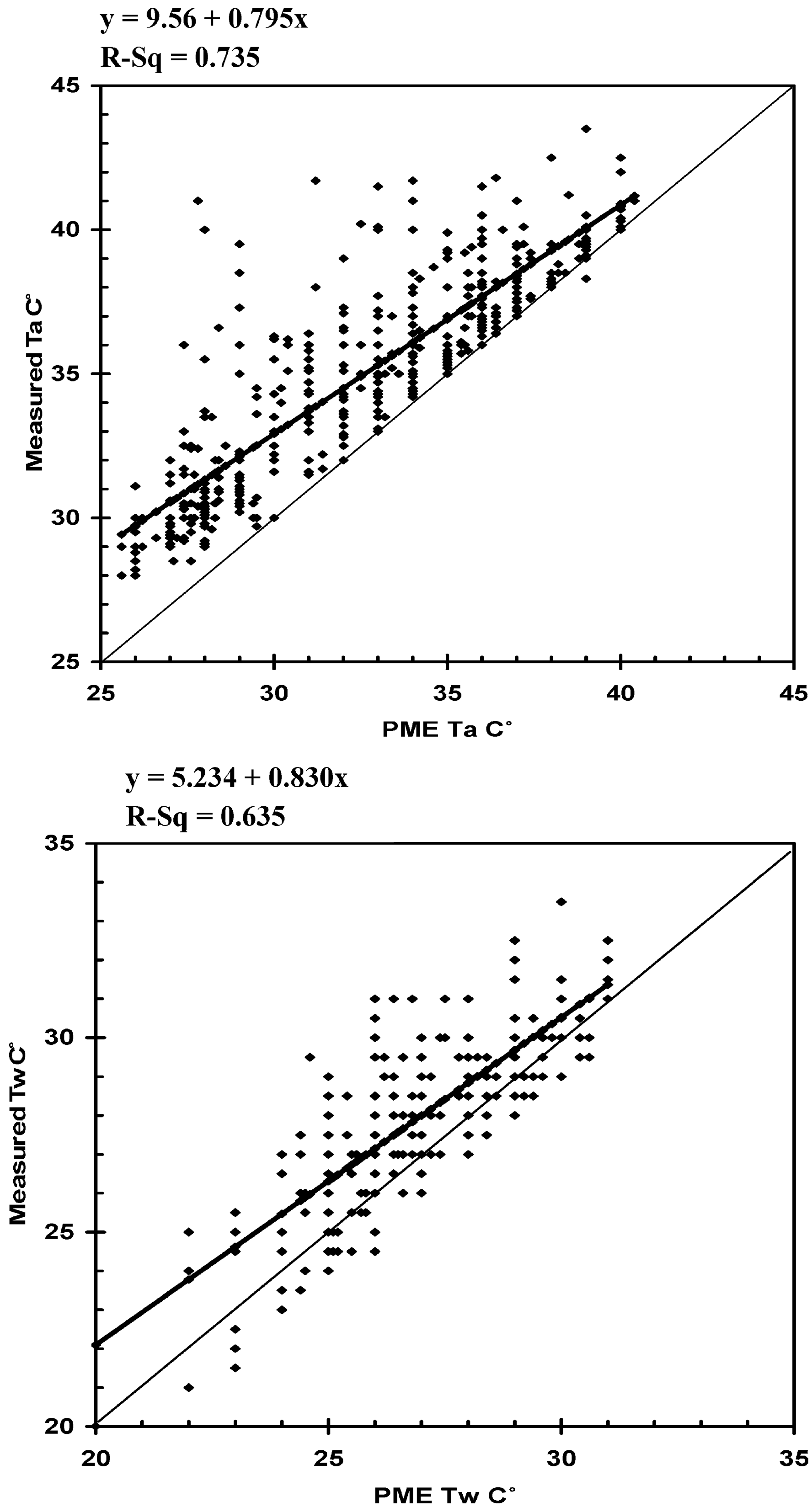


Fig. 2 Linear regression plots of the measured air temperature (T_a), and wet bulb temperature (T_w), with the PME forecasted values

Table 2 Period of job involvements of the air traffic control coordinators of KAAIA during study period (July–September 2003)

Employee number	Date (2003)	Shift	Periods of job involvement (min)			
			Around planes	Inside planes	In office	Total
1	Aug. 2	Afternoon	81	83	316	480
2	Aug. 5	Afternoon	80	64	336	480
3	Aug. 10	Afternoon	93	89	334	516[a]
4	Aug. 12	Afternoon	31	180	269	480
5	Aug. 17	Afternoon	98	81	301	480
6	Aug. 18	Afternoon	134	109	267	510[a]
7	Aug. 19	Afternoon	117	113	250	480
8	July 7	Afternoon	99	110	311	520[a]
9	Aug. 20	Afternoon	297	94	138	529[a]
10	July 21	Afternoon	89	35	373	497[a]
11	July 22	Afternoon	103	72	307	482
12	Aug. 22	Afternoon	78	110	292	480
13	Aug. 23	Afternoon	56	151	273	480
14	July 28	Afternoon	48	114	318	480
15	July 29	Afternoon	49	180	291	520[a]
16	Sept. 1	Morning	101	52	329	482
17	Sept. 2	Morning	119	100	284	503[a]
18	Sept. 3	Morning	59	167	259	485
19	Sept. 5	Morning	35	142	310	487
20	Sept. 6	Morning	92	182	222	496[a]
21	Aug. 7	Morning	34	135	311	480
22	Sept. 7	Morning	45	105	330	480
23	Aug. 14	Morning	47	119	333	499[a]
24	July 24	Morning	74	114	292	480
25	Aug. 25	Morning	63	106	326	495[a]
26	Aug. 26	Morning	62	138	300	500[a]
27	Aug. 29	Morning	48	140	292	480
28	Aug. 30	Morning	64	128	295	487
29	July 31	Morning	122	72	286	480
30	Aug. 31	Morning	37	177	268	482
31	Sept. 9	Night	88	115	291	494[a]
32	Sept. 12	Night	113	109	255	477
33	Sept. 13	Night	19	106	381	506[a]
34	Sept. 14	Night	31	38	410	479
35	Sept. 15	Night	19	35	426	480
36	Sept. 16	Night	51	106	323	480
37	Sept. 17	Night	69	59	352	480
38	Sept. 18	Night	66	145	311	532[a]
39	Sept. 19	Night	107	91	282	480
40	Sept. 20	Night	86	37	357	480
41	Sept. 21	Night	50	28	402	480
42	Sept. 22	Night	75	33	372	480
43	Sept. 23	Night	60	90	351	501[a]
44	Sept. 25	Night	81	90	309	480
45	Sept. 26	Night	55	51	377	483
Mean (SD)			76.1 (44.3)	102.1 (42.4)	311.4 (51.2)	490.0 (14.8)

[a] The involvements of some employees extended to the next shifts (more than 10 min)

measurements at the morning with differences around 5°C which became lower by increasing T_a during the day, until these differences were minimized at noon, afternoon and evening, but increased by night and at midnight. On the other hand, the T_w measurements were closer with the PME values, than the T_a, at all measurements; however, differences between the measured T_w and the PME values around 1–2°C were observed lately after midnight and at the morning. (Table 1, Fig. 2).

The observed difference may be attributed to the augmentation of the climatic thermal conditions by the heat dissipated from the operating vehicles and equipment in service around the plane(s) and the heat resulted from their exhaust. The latter is, in turn, affected by the wind direction, leading to considerable increase in Ta if directed towards the heat measuring locations in the work stations, while having minimal effect if directed away from the measuring locations. The T_w, however, might be also affected by the temperature of the exhausts and its water content, by wind direction.

Naturally, the T_g measurements during the day time are higher than the T_a measurements; reaching their maxima at noon and afternoon, and reduced to their minimal values at night. Worthy noting that the tax ways, ramps and apron where the planes land and get ready for departure, and where the ATCC perform their jobs, are constructed of concrete blocks (one meter in depth).

Consequently, the average WBGT in the work stations throughout the study period and in 95% of the measurements (i.e. mean ± 2 standard deviations) ranged from the lowest levels of 28.6–3.8 and 28.3–1.4°C at midnight and the highest levels of 32.9+1.8 and 33.4+2.6°C at noon and afternoon, around large planes and small planes, respectively (Table 1). The ambient heat is the factor contributing most to the heat load at these work stations, particularly in summer; meanwhile, augmented by heat dissipated from operating vehicles and equipment in service around the planes, and the heat of their exhaust, as demonstrated by the difference between the measured T_a and T_w, and the values forecasted by PME (Table 1, Fig. 2). For example, all the T_a measurements are higher than the PME forecasted values, except for a few odd readings; meanwhile, having good correlation with r^2=0.735 (Fig. 2).

Appropriate methods to reduce the presently reported ATCCs' heat exposure around serviced planes were considered, ranging from technical to administrative methods. The engineering methods appeared to be of limited application to the control of ATCCs heat exposure. On the other hand, the option of controlling their heat exposure, administratively, by re-arranging the work schedule during their shifts appeared to be appropriate, since the climates inside the planes (where ATCCs carry out inspection), the cars (where they are transported), and the office (where they rest) are, all, conditioned. For example, the average WBGT levels for 95% of the measurements inside the planes ranged from the lowest reading of 21.7–3.4 and 23.8±3.8°C at midnight and morning, and the highest 23.2+3.4 and 24.6+2.8°C at noon in large planes and in small planes, respectively; while the levels in office ranged from the lowest 19.4–1.4°C at night to the highest 21.6+3.6°C at noon.

The evaluation of the compliance of the ATCCs heat exposure with the Threshold Limit Value (TLV®) recommended by ACGIH® (2006) required a breakdown of their activities as related to metabolic rate and time involvement. The ATCCs work in three distinct locations where the activities are mostly similar, within each one, as summarized below.

(a) *In ramp*: Assuring arrival of all concerned personnel and equipment before flights' arrival and supervising their activities till departure as related to: safety and convenience of air craft

Table 3 Distribution of heat exposure of the air traffic control coordinators of KAAIA

WBGT (°C; TWA)	Frequency distribution		Cumulative	
	Number	Percent (%)	Number	Percent (%)
18.0	1	2.2	1	2.2
20.0	2	4.4	3	6.7
21.0	7	15.6	10	22.2
22.0	16	35.5	26	57.8
23.0	9	20.0	35	77.8
24.0	4	8.9	39	86.7
25.0	3	6.7	42	93.3
26.0	1	2.2	43	95.6
27.0	1	2.2	44	97.8
30.0	1	2.2	45	100.0
Total	45	100.0	45	100.0

location, readiness of air conditioning units and stairs services, and safe flight fueling; as well as passengers' evacuation and boarding, and other ground support services like: catering, passengers' transfer to and from terminal, luggage and cargo evacuation and loading, transit passengers and luggage and connecting flights, and special services like request for medical services and care for children.

(b) *Inside planes*: Assuring cabin, catering, fleet, luggage and cargo services, passengers' seating, readiness for flying, availability of flight information and related documents, and coordinating with concerned sections and bodies as related to delays and other unexpected events for taking actions.

(c) *In office*: Preplanning, following-up, documenting, analyzing, evaluating and reporting about the arriving and departing flights, including daily scheduling and coordination with airport operations and related sections for flight services in ramp, load control, passengers' services and other required information and special services.

When the above–stated ATCC work activities were compared with the examples of the activities described in the ACGIH®-TLV® list(ACGIH 2006), the activities in ramp and inside plane have been classified as moderate work activities, while in office as light work activity.

The time involvements of the 45 ATCCs in the three work locations in randomly selected days are presented in Table 2. These data were used to compute the Time-Weighted Average (TWA) heat exposure for them, expressed in WBGT °C, which are presented in Table 3. In spite of the above-reported high WBGT levels of the ATCCs' thermal environment, only 3 operators have TWA-WBGT exposure higher than the TLV® level of 25°C, recommended by ACGIH® (2006), for safe heat exposure of non-acclimatized workers conducting medium type of work. The TWA-WBGT exposure for the 3 operator were 26, 27 and 30°C, while the TLV®-WBGT for acclimatized workers is 27.5°C. The safe heat exposure for these operators might thus be corrected by further reducing their heat exposure in the work stations around the planes to the optimal periods. Worthy noting that mostly all the studied ATCC, are acclimatized to heat. However, precautionary measures calling for more hot days exposures and employing non-acclimatized employees should be considered.

Conclusions and recommendations

It may be concluded from the present study that the air traffic control coordinators (ATCC) are exposed to heat stress levels considerably higher than the TLV® of 25°C of WBGT, recommended for safe heat exposure of non-acclimatized workers, at locations around ground serviced arriving and departing planes in KAAIA. The ambient heat is the factor contributing most to the heat load, particularly in the summer; meanwhile, augmented by heat dissipated from operating vehicles and equipment in service around the planes, and the heat of their exhaust. However, the shift-period-schedule implemented by SAUDIA reduced mostly all operators' exposures to acceptable levels. The work schedules of the few left (6.7%, 3/45) might be further corrected to achieve safe exposures.

Acknowledgment The authors would like to thank engineers Mohamed A. Abdel-Wahab and Wadea A. Bokhari for their effort in data collection.

References

Al-Jiffry, M. A., Al-Idrissi, M. M., Al-Jiffry, M. S., Jamil, A., & Erturk, F. (1990). Heat stress assessment in the industrial facilities (A Case Study). *Journal of Environmental Science and Health*, *A25*, 209–230.

Bruel & Kaier (1985). *Instruction manual: Heat stress monitor type 1219*. B & K, DK-2850. Naerum, Denmark.

Hisamatsu, (1985). *Instruction sheet:Model 3-1440 thermal anemometer*. Tokyo, Japan: Hisamatsu Manufacturing Co. Ltd.

Kielblock, J. (2002). Heat stress management: An occupational hygiene perspective. *Journal of the Mine Ventilation Society of South Africa*, *25*(1), 24–27.

Leithend, C. S., & Lind, A. R. (1964). *Heat stress and heat disorders*. USA: Davis Co. Philadelphia, Pa.

Minard, D. (1966). Evaluation of heat stress under working conditions. *Proceeding of the VI conference of the industrial council for tropical health*. Boston, Ma, USA: Harvard School of Public Health.

MMWR (1984). Fatalities from occupational heat exposure. *MMWR*, *33*, 410–412 (July 20).

MMWR (1995). Heat related illness and death—United States 1994–1995. *MMWR*, *44*, 465–8.

MMWR (1998). Heat related morality—United States 1997. *JAMA*, *280*, 316–7.

Mutchler, J. E. (1991). "Heat stress": Its effects, measurement and control. In C. D. Clayton, & F. E. Clayton (Eds.) *Patty's industrial hygiene and toxicology,* vol. 1-A ((pp. 399–430)4th ed.). New York, NY, USA: John Wiley.

NIOSH (1986). *Criteria for a recommended standard. Occupational exposure to hot environment*. National Institute for Occupational safety and Health, Cincinnati: Document # 83–113.

NIOSH (1993). *Fatal Injuries to workers in the United States 1980–1989. A Decade of Surveillance*. National Institute for Occupational Safety and Health, Cincinnati: Document # 93–108.

Noweir, M. H., Moreb, A. A., & Bafail, A. O. (1996). Study of heat exposure in the work environment in Jeddah. *Environmental Monitoring Assessment*, *40*, 225–237.

Ramsey, J. D., & Beshir, M. Y. (1997). "Thermal standards and measurement techniques". In S. R. DiNardi (Ed.) *The occupational environment—its evaluation and control* (pp. 660–691). FairFax, Va, USA: Amer. Ind. Hyg. Assoc.

Srivastava, A., Kumar, R., Joseph, E., & Kumar, A. (2000). Heat exposure study in the work place in a glass manufacturing unit in India. *American Occupational Hygiene*, *44*, 449–453.