Thermal Environment and Productivity in Sedentary Activities. A Short Review

Quelhas Costa, Emília[a]; Santos Baptista, João[b]; Tato Diogo, Miguel[c]
PROA/LABIOMEP/CIGAR/Faculdade de Engenharia da Universidade do Porto, Portugal, [a] eqc@fe.up.pt, [b]jsbap@fe.up.pt, [c] tatodiogo@fe.up.pt

ABSTRACT
Physical effects caused by thermal environment, that may vary from cold, moderate to more severe conditions, adversely affect health and safety and may also affect productivity and workers' attention. This paper aims to provide a brief review concerning the influence of thermal environment on productivity in sedentary activities, through the presentation of the research lines and relevant studies in this field. The study was conducted through a systematic review, focused on a research question and according to adequate keywords. Based on content analysis of selected literature it appears that differences in temperature and humidity, whatever their source, may cause changes in the performance of workers at various levels, including productivity, while being detrimental to the health and safety of workers. Thermoregulation is an essential parameter, amid the ones requiring monitorization, depending on individual factors. In this study, other two topics are highlighted as fundamental to the study of the effects of thermal environment and productivity: climatic conditions and neutral thermal sensation. Considering the results it was concluded that there are many factors that affect worker productivity, however the environmental conditions have a great significance. The results show that thermal discomfort caused by air temperature is a relevant negative effect on performance. This effect is demonstrable from the changes in behaviour, mood, fatigue, motivation, reaction speed and increased absenteeism. Further studies are needed to clarify the conditions of ideal thermal environment related to high productivity, since the temperature known as the comfort temperature is not directly related to this factor.

KeyWords: Productivity, Thermal environment, Office Workers, Hot.

1. INTRODUCTION

The relationship between thermal environment and productivity as well as its quantification is an increasingly pertinent issue. In order to contribute to a systematization of knowledge in this field, a first analysis, in terms of scientific literature, is presented in this summary.
To a better understanding of the relationship between productivity, performance and activity, it is essential to define these three concepts; Parsons (2003) definitions were selected for this review: "Activity" is whatever people do, to achieve a goal, and may involve physiological or psychological factors. When these factors are carried out successfully, it means that the activity is performed. The term "Performance" when applied solely does not make sense and should always be associated with a task and related purpose, or will be conducting activities to achieve the objective. Finally "Productivity" is usually associated to the objectives of the organization and translates into a value that corresponds to what extent the activities have provided in terms of performance objectives of the system (Parson, 2003**).**
The physical effects caused by hot and humid thermal environment can vary from a mild state, with the sensation of thirst or heat, causing in this case, discomfort or lack of attention affecting the production, up to a more severe condition that can lead to heatstroke, collapse and unconsciousness and even death.
Productivity is one of the most important factors affecting the overall performance of any organization, from small to large companies (Niemela et al., 2002). Heat can cause physiological stress, particularly in people with high levels of physical activity. However, even people with other kind of activities have the same problem due to inherent physiological and individual aspects. For this reason the study of the relationship between thermal environment and productivity is complex because it depends on environmental factors such as: air temperature, air velocity, radiant temperature and relative humidity and individual factors, such as physical activity and clothing, and consequently, do not have the same effect in all persons.
Besides the factors mentioned above, Hole (2009) found a significant correlation between productivity indicators, health and organizational attributes in a study carried out in India. This study showed that companies reporting more organizational problems also have more performance problems (Hole, 2009). Problems that are sometimes related to working conditions, like for instance lack of resources and facilities: machines, manual material handling, workers motivation, training workers, hot work environment, once in this study in India the temperature in the factory could be around 46 *ºC* in the summer months. The other problems in terms of environment were noise and dusty environment. Due to that, managers receive workers' complaints of fatigue, back pain, upper –body and neck pain and hand or arm soreness.
This paper intends to present a short review regarding the influence of thermal environment upon productivity in sedentary activities, through the presentation of the research lines and relevant studies published in this field.

2. MATERIALS AND METHODS

The study was conducted through a systematic review, focused on a research question and according to adequate keywords. Initially the collection of articles it was independently of the year of publication, and in the second phase,

priority was given to articles dating back to the last decade. The keywords used were: "Productivity" in the search field Title and "Thermal environment" in the Subject, and 448 results were listed. Of these, 392 were eliminated corresponding to the database Zentralblatt Math, leaving 56 papers in other three databases: Academic Search Complete (1), Current Glad (20) and Web of Science (35). As a criterion of restriction, only articles from the same keywords were analysed, with the addition of one of the following three search terms: Office Workers and the Indoor Environment, refined in the field of research authors. With this refinement left a total of 17 articles, with priority given to those published more recently, in view of the meta-analysis by Pilcher (2002). The selection was based on the information contained in the abstract of each articles.

3. RESULTS.

Extreme environment conditions are common in several industries. Such places include: iron, steel and nonferrous foundries, ceramics operation, glass and calcium carbide manufacturing, mining operating, electrical utilities (particularly in boiler room), farming operations, bakeries, confectioneries, restaurant kitchens, laundries, chemical manufacturing facilities, airport personnel working on hot tarmac, and also is some military and special facilities such as aircrafts and submarines. This subject is vital to a lot of workers especially due to safety and health problems. The adverse conditions that workers are exposed to, affect individual's ability. With so much blood going to the external surface of the body, relatively less goes to the active muscles, the brain, and other internal organs; strength declines; and fatigue occurs, alertness and mental capacity also may be affected, workers who must perform delicate or detailed work may find their accuracy suffering.

Based on the content analysis of selected literature it appears that exposure to different temperatures and levels of humidity, whatever their source, may cause changes in the performance of workers at various levels, including production aspects, while being harmful to health and safety of workers. Costa (2010) asserts that as a result of such exposure are frequent changes in behaviour, mood, increased distractibility, increased physical fatigue, discouragement, loss of speed in performing tasks, reducing the degree of attention and precision as well as increased absenteeism.

Blyissen (2009) refers that productivity depends upon many aspects: well-being, job satisfaction, technical competence, career achievements, home/work interface, relationship with others, personal circumstances, organizational matters, etc., and also environmental factors (indoor and outdoor environment). The same author sustains that productivity is measured in three different ways:

- Objectively: by measuring the speed of working and the accuracy of outputs by designing very controlled experiments with well-focused tests;
- Subjectively: by using self-estimated scales and questionnaires to assess the individual opinions of people concerning their work and environment;
- Combined measures: using some physiological measures such as brain rhythms to see if variations in the patterns of the brain responses correlate to responses assessed by questionnaires.

This research highlights several topics considered by different authors as essential to develop the relation between thermal environment and productivity, such as: individual factors, climatic conditions and neutral thermal sensation.

3.1 Individual factors

People are different and some people are extremely sensitive when exposed to environmental changes, due the individual factors that differ from person to person, namely thermoregulation. For this reason it may, therefore, be difficult to keep all occupants comfortable at the same time in one space. Human thermal sensation is mainly related to the thermal balance of the human body as a whole. This balance is influenced by physical activity and clothing as well as by the environmental parameters, (Fanger, 1986).

Thermoregulation is one the critical parameters when studying human behaviour at high temperatures. Thermoregulation depends on: age, gender, body mass index, body fat rate, surface area, sweating mechanism, hormonal differences, among others, (Falk, 1998).

On the other hand the variables controlled by Nielson (1993), in a study of heat acclimation were: core temperature (esophageal), sweating, oxygen consumption, heart rate, heart rate response, blood flow, leg (Leg blood flow – LBF), forearm blood flow (Forearm blood flow- FBF), skin temperature, plasma volume, blood constituents (Hct, Hb, glucose and lactate concentration, hormonal analysis (catecholamines, adrenaline, etc.).

It was concluded from the article published by Nielson (1993), that heat acclimation may take a different course depending on the type of environment, for instance, hot and dry effects versus hot and humid, as well as exercise. The high core temperature was a critical factor to fatigue caused by heat stress, both before and after acclimation (Nielson et al, 1993). According to the research presented by Ribeiro (2010), the continuous increase in the value of the internal temperature will cause the achievement of a certain critical value and compromised physical performance, which has been referred to as ranging between 39,1 ^{o}C and 40,1 ^{o}C (rectal temperature), athletes tend to finish the race due the fatigue with rectal temperature at around 40 ^{o}C, (Ribeiro, 2010).

In a recent study published by Zhao (2009), statistics analysis using Excel was applied trying to establish the human tolerance time and productivity model in a hot and humid environment. The main objective was to determine the safe working time for workers in a hot and humid environment and also to provide the performance rate of productivity under

these conditions. It was concluded that work done in warm and humidity, for long periods, not only may cause damage to human health and decrease productivity, but also cause accidents. For that purpose, it was analysed the physiological indices of human body and productivity performance in a combination of six different temperatures (30, 32, 34, 36, 38, 40 *ºC*) and four levels of humidity (40%, 60%, 80%, 90%). In this experience some physiological indices such as body temperature, blood pressure and heart rate were tested every 20 minutes. To make the evaluation of productivity (%) it was used the ratio of labour performance in extreme environment to labour performance in comfortable environment at the same time.
Witterseh (2004), also confirms that dangerous behaviour associated to high temperatures has an impact on productivity and may potentiate the accident. For this reason, Kenefick (2007) states that studies of occupational accidents show a lower rate during the winter months than in the summer, when sweat losses would be greatest. It is in warm-hot environments that fluid turnover would be highest and workers most likely to become dehydrated.

3.2 Climatic Changes

With temperatures expected to increase because of climate change, it is essential to study the health outcomes of different conditions of temperature and humidity, once it is an external condition that compulsorily will affect the general population.
With anticipated effects of global warming, the conditions for manual work in many types of industry and in agriculture get worse. Heat stress in work places will increase and affect strain and performance of workers and their productivity, (Holmer 2010).
To maintain productivity during a heat wave, according to Parsons (2009) it is necessary to provide thermal comfort. But, this is not always possible and what happens is that under conditions of high heat the productivity decreases. There are a variety of studies about the effects of heat on manual dexterity and cognitive performance. However the more direct impact factors on productivity are: time off task, caused by the cessation of work or because heat have caused distraction. This applies to people at home, offices and other workplaces. Until this date the relationship between the level of distraction caused by the heat and the level of heat stress is not yet known (Parsons, 2009).
Akimoto (2009), in his study made the measure in summer, autumn, winter of 2005, and summer of 2006. To understand the thermal environment in working zones in an office, various physical factors of thermal environment were measured, such as horizontal temperature and humidity distributions, vertical temperature distribution, airflow speed and radiant temperature. The thermal environment was also measured using a mobile device cart to understand the environment that the workers were exposed to in the task zone. It was found that the rate of hours occupants stay in task zone during working hours depends, on the type of job, and workers are not frequently repeating sit-down and leaving-out, so it is thought that metabolic rate while occupants are seating is almost constant. But while leaving from the seat, both activity level of occupant and exposed thermal environment is greatly different one by one. It was confirmed that an increase in metabolic rate according to worker's behaviour influenced on thermal and comfort sensation, (Akimoto 2009).
According to the same author at the 3rd Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3) that took place in 1997, the Kyoto Protocol was adopted to fight the global climate change. As a measure to achieve this goal, it is recommended by the Japanese Government to set the air temperature in office building to be 28 *ºC* in summer to reduce CO_2 emission. In office buildings, it is important not only to reduce energy consumption but also to establish comfort environment, which may maximize human productivity. (Akimoto, 2009).
According to a study from Tanabe (2007), a survey conducted in a call-center showed the decline in performance in a warmer environment; and it was different among the task types. He showed in their study that the subject feeling more mental fatigue, and more cerebral blood flow was required to maintain the same level of task performance, in a hot condition than at thermal neutral condition. In the same study it was suggested that the benefit by reduction in the running cost and reduction of the CO_2 emission would be minimal compared to the possible cost generated by the performance decrement, (Tanabe et al., 2007).

3.3 Neutral Thermal Sensation

Once the aim of this paper is to make a review concerning the thermal environment and productivity in sedentary activities it is important to have in mind the first considerations about comfort requirements during winter and summer conditions in the activities studied.
According to Fanger (1986) the PMV (Predicted Mean Vote) and the PPD (Predicted Percentage of Dissatisfied) indices express warm and cool discomfort for the body as a whole. Furthermore, from a laboratory test that was carried out in a climatic chamber by Chung (1990) it was found a neutral temperature of 24,9 *ºC* under sedentary activities and with clothing level of 0,6 *clo*.
Thermal dissatisfaction may also be caused, by an unwanted heating or cooling of one particular part of the body (local discomfort). This can be caused by a too high vertical air temperature difference between head and ankles, by a too warm or too cool floor, or by a too high air velocity (draft) or by a too high radiant temperature asymmetry. Limits are listed in the ISO standard for light, mainly sedentary activity during winter (Table 1) and summer (Table 2) conditions. If these limits are met, it is expected that no more than 5 – 10 % of the occupants will feel uncomfortable due the local heating or cooling of the body caused by each of the below–mentioned factors, (Fanger 1986).

Table 1 – Comfort requirements during winter conditions and light, mainly sedentary activity.

Situation	Conditions
Operative Temperature to be between:	20 and 24 *ºC*
Vertical air temperature difference between 1,1 *m* and 0,1 *m* above floor (head and ankle level) to be less than:	3 *ºC*
Surface temperature of the floor to be normally between:	19 and 26 *ºC*
Floor heating systems may be designed for:	29 *ºC*
Mean air velocity to be less than:	0,15 $m.s^{-1}$
Radiant Temperature asymmetry from the windows or other cold vertical surface: Radiant temperature asymmetric (in relation to a small vertical plane 0,6 *m* above the floor) to be less than:	10 *ºC*
Radiant Temperature asymmetry from a warm (heated) ceiling: Radiant temperature asymmetry (in relation to a small horizontal plane 0,6 m above the floor)to be less than:	5 *ºC*

Fanger 1986

Table 2 – Comfort requirements during summer conditions and light, mainly sedentary activity.

Situation	Conditions
Operative Temperature to be between:	23 and 26 *ºC*
Vertical air temperature difference between 1,1 *m* and 0,1 *m* above floor (head and ankle level) to be less than:	3 *ºC*
Mean air velocity to be less than:	0,25 $m.s^{-1}$

Fanger 1986

Tables 1 and 2 show a summary of the temperature limits for winter and summer required to obtain the desired level of comfort.

In the table 3, it is indicated a summary of different studies of thermal comfort in sedentary activities. A neutral thermal sensation is the feeling of neither slightly warm nor slightly cool (Chow et al 2010). Tanabe, carried out a thermal comfort study in Japan with 172 college–age subjects wearing 0,6 *clo* standard clothing, and the neutral temperature was found at 26,3 *ºC* under sedentary activities (Tanabe et al 1987).

Table 3 – Different studies of Thermal Comfort conditions in Sedentary Activities.

Conditions of Thermal Comfort in Sedentary Activities	Country	Authors
26,3 (0,6 *clo*)	Japan	Tanabe et al 1987
26 *ºC* (air velocity 0,4 $m.s^{-1}$)	Brazil	Candido et al 2010
30 *ºC* operative temperature (air velocity 0,9 ms^{-1})	Brazil	Candido et al 2010
26 *ºC* (air velocity 0,2 ms^{-1}); 50 %- 60 % HR	Thailand	Yamtraipat 2005
25,4 *ºC* (neutral temperature for people that have AC acclimatization)	Thailand ,	Yamtraipat 2005
26,3 *ºC* (neutral temperature without AC acclimatization)	Thailand	Yamtrapat 2005
24,9 *ºC* (0,6 *clo*) Climatic Chamber	Hong Kong	Chung 1990
25,4 *ºC* (air velocity at 0,1-0,2 ms^{-1}) 0,55 *clo* metabolic rate *1met* (laboratory)	Hong Kong	Chow 2010

On the other hand in Brazil in a situation of comfort, it was found a temperature of 26 *ºC*, air velocity 0,4 ms^{-1} and 0,9 ms^{-1} was required if operative temperature reached 30 *ºC*,(Candido et al., 2010) and in Thailand it was suggested 26 *ºC*, 50-60 % RH and 0,2 ms^{-1} air velocity to be the thermal comfort standards for air-conditioning design; the neutral temperature for the group of people having AC acclimatization behaviour at home and at work was about 25,4 *ºC*, whereas 26,3 was found for the other group (Yamtraipat, 2005).

More recently by Chow (2010) in a laboratory – based thermal comfort survey was conducted in Hong Kong with around 300 educated Chinese subjects and the result analysis shows that, like in many other Asian cities, the thermal sensation of the Hong Kong people is sensitive to air temperature and speed, but not much humidity. With bodily air speed at 0,1-0,2 ms^{-1}, clothing level 0,55 *clo* and metabolic rate 1 *met*, the neutral temperature was found be around 25,4 *ºC* for sedentary working environment.

In the following overview of different studies, thermal comfort in sedentary activities is referred to and when it was compared with the requirements presented by Fanger, where a slight discrepancy in different temperatures is observed. In additions the average annual temperatures in the studied countries are: Japan (max. temperature 30 *ºC*; min. temperature 1 *ºC*); Hong Kong (max. temperature 34 *ºC*; min. temperature 8 *ºC*); Thailand (max. temperature 33 *ºC*; min. temperature 20 *ºC*) and Brazil (max. temperature aprox. 30 *ºC* and min.20 *ºC*).

4. DISCUSSION

Although the relation between temperature and productivity may vary according to several factors including: individual, climatic changes, neutral thermal sensation, there are other factors such as building characteristics and the type of activity developed that should be taken into consideration.

The relation between productivity and temperature according to research is shown in table 4. Seppänen (2005), inferred through a simple example, that the use of ventilation during the night, improves indoor increasing productivity (Seppänen et al., 2005). However, the same author also mentions the existence of studies that indicate that there is no significant relationship between temperature and productivity when it comes to values within the comfort zone, but when these values ate between 24,8 *ºC* and 26 *ºC*, there a 15 % decrease in productivity. On the other side, in another different environment and activity, in the case of a textile manufacturing plant, it was registered an 8 % reduction in productivity for variations in temperature between 23,9 *ºC* and 32 *ºC* (Seppänen, et al 2005).
When approaching others activities, productivity may exhibit different values. Eston (2005), points out some values in gold mines in South Africa, referring to acclimated workers, (miners accustomed to a new climate or environment), working during three consecutive hours. Such data indicate that from a certain temperature the worker's income is reduced drastically, ranging from 100% yield with a temperature of 28,9 *ºC*, and 25 % yield with a temperature of 37 *ºC* (Eston, 2005).
Although some studies indicated that the best environment for working is the thermally comfortable environment, or the most comfortable temperature yields optimal work performance, the relative humidity also affects productivity. A maximum relative humidity between 50% and 65% is normally provided at the design stage and higher relative humidity affects thermal comfort (Zhao, 2009).

Table 4 – Relation between productivity and temperature according to research

Temperature	Productivity
Around 25 *ºC* (in call center)	Decrease 1,8 % for each *ºC* that increase (1)
Above 25 *ºC* (in call center)	Decrease 2,2 % for each *ºC* that increase (2)
Between 24,8 *ºC* a 26 *ºC*	Decrease 15 % (3)
In a textile manufacturing plant (23,9 *ºC* to 32,2 *ºC*)	Decrease 8 % (4)
Mines in South Africa 28,9 *ºC*	100 % of Productivity (5)
Mines in South Africa 32,8 *ºC*	75 % of Productivity (5)
Mines in South Africa 35,3 *ºC*	50 % of Productivity (5)
Mines in South Africa 36,4 *ºC*	30 % of Productivity (5)
Mines in South Africa 37 *ºC*	25 % of Productivity (5)

(1), (2), (3) e (4) Seppänen et al., 2005 (5) Eston, 2005

5. CONCLUSIONS

Considering the results it was concluded that thermal environment affects the human being, thus causing an impact upon the activity which in turn influences performance and productivity. It was also inferred that there are many factors affecting workers' productivity. However, environmental conditions have a notable significance and may have consequences of various kinds. The results from different papers show that thermal discomfort caused by high air temperature has a negative effect on performance. This effect is evidenced by changes in behaviour, mood, fatigue, motivation, reaction speed, increased absenteeism and stress. The relationship between the level of distraction caused by heat and the thermal stress level is still not yet known. Therefore, further studies are needed to clarify the conditions of ideal thermal environment related to high productivity, since the temperature known as the comfort temperature is not directly related to high productivity, as attested the findings of some authors. For that reason it is advisable to develop further studies using different combinations of relevant factors including physiological factors.

6. REFERENCES

Bjarne W. Olesen (2005) Indoor Environment- Health-Comfort and Productivity International Center for Indoor Environment and Energy, Technical University of Denmark Gender: male

Bluyssen Philomena M. Towards new methods and ways to create healthy and comfortable buildings TNO Built Environment and Geosciences, P.O. Box 49, 2600 AA delft, The Netherlands Building and Environment 45 (2010) 808–818

Bodil Nielsen, J. R. S. Hales, S. Strange, N. Juel Christensent, J. Warberg: and B. Saltin. From the August Krogh Institute, University of Copenhagen, the Department of Internal Medicine and Endocrinology, Herlev Hospital, University of Copenhagen, and the Department of Medical Physiology C, Panum Institute, University of Copenhagen, Denmark. Human circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment. Journal of Physiology (1993). 460. pp. 467-485

C. Cândido, b, R.J. de Dearc, R. Lamberts, L. Bettencourt Air movement acceptability limits and thermal comfort in Brazil's hot humid climate zone. Building and Environment Volume 45, Issue 1, January 2010, Pages 222-229 International Symposium on the Interaction between Human and Building Environment Special Issue Section

Costa, Emília Rosa Quelhas, Baptista, João Santos, Diogo, Miguel Tato, Magalhães, António Barbedo, Hot Thermal Environment and its impact in productivity and accidents in João Santos Baptista, A. S. Miguel, Gonçalo Perestrelo, Nelson Costa, Mónica Barroso, Pedro Arezes, P. Carneiro, P. Cordeiro, Rui Melo, International Symposium on Occupational Safety and Hygiene - SHO 2011, pp.211-215, 2011

Eston, S.M. 2005. Problemas de conforto termocorporal em minas subterrâneas. Revista de Higiene Ocupacional. 13, 2005, Vol. 4, pp. 15-17.

Falk B. Ribstein Center for Research and Sport Medicine Sciences, Wingate Institute, Netanya, Israel. Effects of thermal stress during rest and exercise in the pediatric population Sports Med. 1998 Apr;25(4):221-40. PubMed U.S. National Library of Medicine National Institutes of Health.

Fanger, P O. 1986. Thermal Environment-Human Requirements. The Environmentalist. Technical University of Denmark, 1986, Vols. Volume 6, Number 4, pp. 275-278.

heat stress: methods for assessment Global Health Action 2010, 3: 5719 - DOI: 10.3402/gha.v3i0.5719.

Ingvar Holmér Climate change and occupational

J.A. Hole, Dr. Mukesh Pande. Worker Productivity, Occupational Health, Safety and Environmental Issues in Thermal Power Plant. Research Scholar R.G. Technological University Bhopal, M.P, India Dy. Registrar (Acad.) R.G. Technological University Bhopal, M.P, India. Proceedings of the 2009 IEEE IEEM

Jan Sundell Prof., MSc. Eng. Dr. Med. Sci Indoor Environments and Health. TxAIRE, University of Texas at Tyler SHB2009 - 1st International Conference on Sustainable Healthy Buildings; Seoul, Korea.6 February 2009

Kenefick, Robert W. e Sawka, Michael N. 2007. Hydration at the Work Site. Journal of the American College of Nutrition, Vol. 26, No. 5, 597S–603S (2007). 2007, Vol. 26.

Lan, Li, Lian, Zhiwei e Pan, Li. (2010). The effects of air temperature on office workers´well-being, workload and productivity - evaluated with subjective ratings. Elsevier - School of Mechanical engineering, Shanghai Jiao Tong University, Shanghai 200240, China

Li Lan, Pawel Wargockib, Zhiwei Liana Quantitative measurement of productivity loss due to thermal discomfort Institute of Refrigeration & Cryogenics, Shanghai Jiao Tong University, Shanghai 200240, China International Centre for Indoor Environment and Energy, Technical University of Denmark, Building 402, DK-2800 Kongens Lyngby, Denmark . Elsevier Energy and Buildings 43 (2011) 1057–1062

N. Yamtraipat, J. Khedari, J. Hirunlabh. Thermal comfort standards for air conditioned buildings in hot and humid Thailand considering additional factors of acclimatization and education level. Solar Energy Volume 78, Issue 4, April 2005, Pages 504-517 Sustainable Energy and Green Architecture

Olli Seppänen, PE; William J. Fisk, PE, David Faulkner (2002), "Control of Temperature for Health and Productivity in Offices

Parsons, Ken. 2003. Human Thermal environments: the effects of hot, moderate, and cold environments on human health, comfort and performance. 2nd ed. London : Taylor & Francis, 2003. ISBN0-415-23793-0(pbk) ISBN:0-415-23792-0(hbk).

Raimo Niemela, Mika Hannula, Sari Rautio, Kari Reijula, Jorma Railio. The effect of air temperature on labour productivity in call centres-a case study. Finnish Institute of Occupational Health, Topeliuksenkatu 41 Helsinki, Finland. Tampere University of Technology, Tampere, Finland. Association of Finnish Manufacturers of Air Handling Equipment, Helsinki, Finland. Energy and Buildings - Elsevier 34 (2002) 759–764

Seppanen OA, Fisk WJ. Some quantitative relations between indoor environmental quality and work performance or health. In: Proceedings of the 10th international conference on indoor air quality and climate; 2005. p. 40–53 [Beijing].

Seppanen, Olli, Fisk, William J e Faulkner, David. 2005. Control of Temperature for Health and Productivity Offices. ASHRAE. 2005, Vols. III, Part 2, pp. 680-686.

Shin-ichi Tanabe1, Naoe Nishihara 2, and Masaoki Haneda 1 PERFORMANCE EVALUATION MEASURES FOR WORKPLACE PRODUCTIVITY Department of Architecture, Waseda University, Japan Research Institute for Science and Engineering, Waseda University, Tokyo, Japan IAQVEC 2007 Oct. 28 - 31 2007.6th International Conference on Indoor Air Quality, Ventilation & Energy Conservation in Buildings.

T:T: Chow; K.F Fong, B. Givoni, Zhang Lin, A.L.S. Chan 2010. Thermal sensation of Hong Kong people with increased air speed, temperature and humidity in air - conditioned environment. Building and Environments 45(2010) 2177-2183.

Tanabe S, Kimura K, Hara T. Thermal comfort Requirements during the summer season in Japan. ASHRAE Transactions 1987;93:564-77

Tham, Kwok Wai e Willem, Henry Cahyadi. 2009. Room air temperature affects occupants`physiology, perceptions and mental alertness. Building and Environment. 5 de April de 2009 T. M Chung, WC Tong ., 1990 Thermal comfort study of young Chinese people in Hong Kong Building and Environment Volume 25, Issue 4, 1990, Pages 317-328.

Witterseh, Thomas e Clausen, David P. Wyon and Geo. 2004. The effects of moderate heat stress and open-plan office noise distraction on SBS symptoms and on the perfomance of office work. 2004, Vols. Inddor Air 2004;14(Supp):30-40.

Zhao, Jing, Zhu, Neng e Lu, Shilei. 2009. Productivity model in hot and humid environment based on heat tolerance time. Building and Environment. 16 de January de 2009, Vol. 44, pp. 2202-2207.