The use of the wearable sensory devices for metabolic rate estimation

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1. Introduction

➢ **Thermal comfort** - occupants' satisfaction with the surrounding thermal conditions

- affects occupant health, productivity and behavior

⇩

a gap between designed and achieved energy savings in buildings

Thermal comfort standards: Predicted Mean Vote (PMV), established by Fanger

$$PMV = f\,(Ta,\ Tr,\ RH,\ v,\ I,\ M)$$

➢ the most critical factor
➢ the most difficult parameter to measure

1. Introduction

➢ Sensing devices:

- useful tool to track user activities during a working day
- secure accurate information to develop an algorithm for indoor air quality optimization
- essential advancements towards personal thermal comfort

➢ Gender differences:

- not merely due to differences in physical characteristics, but due to innate physiologic gender differences as well
- women are more critical about their thermal environments and more sensitive to both cold and hot room temperatures - confirmed by studies concerning sick building syndrome which indicate that females experience sick building symptoms more often than the male population in the same building

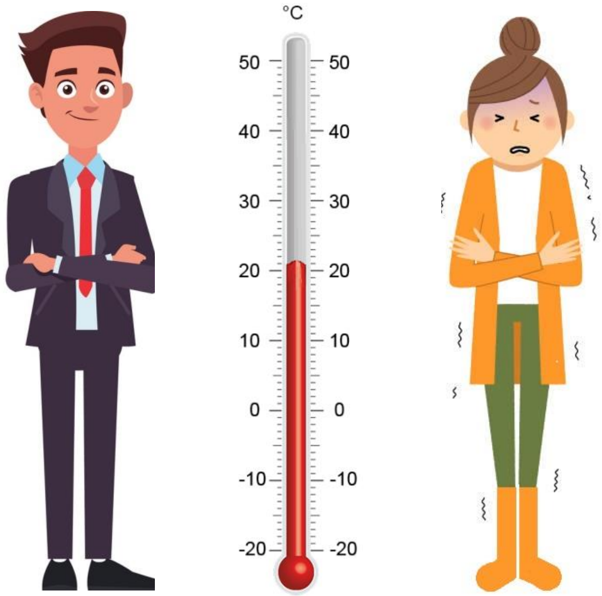
1. Introduction

Table 1. Literature review on gender differences

Study	Study type	Gender differences	Description
Fanger [1]	Laboratory study	No significant differences	Females tended to be more sensitive to an optimum deviation.
Beshir MY, Ramsey JD [24]	Laboratory study	Difference found (significance unreported)	Females tended to feel more uncomfortable than males at both high and low temperature extremes.
Muzi G. et. al. [25]	Field survey	Difference found (significance unreported)	Females reported feeling hot more often than males.
Cena K, de Dear R. [26]	Field study	Significant difference found	Females expressed more thermal dissatisfaction than males.
Griefahn B, Kunemund C.[27]	Laboratory study	Significant difference found	Females reported feeling hot more often than males due to draft.
Nagashima K. et. al. [28]	Laboratory study	Difference found (significance unreported)	Females felt cold in thermal environments in which most males feel thermally comfortable.
Nakano J, Tanabe S, Kimura K. [29]	Field survey	Difference found (significance unreported)	Neutral temperature reported 3.1 °C higher for females than for males.
Parsons KC [30]	Laboratory study	Difference found (significance unreported)	Differences found in cool conditions; females tended to be cooler than males.
Pellerin N., Candas V. [31]	Laboratory study	Difference found (significance unreported)	Females accepted noisier environments but are more sensitive to thermal deviation than males.
Karjalainen S. [32]	Field survey	Significant difference found	Females tended to be more critical of their thermal environments, and were more sensitive to both cold and hot room temperatures.
Chaudhuri T. [18]	Laboratory study	No significant differences	No difference in thermal preference, Women portrayed greater satisfaction in terms of comfort and humidity. Men were more sensitive yet tolerant of the ther-mal conditions.
Zhai Y. et.al. [10]	Laboratory study	No significant differences	No gender differences found in metabolic rates of sitting, standing and walking Women have higher HR at the same activity level

1. Introduction

➢ Different individuals have a different scale of thermal comfort, as a result of physiological difference, the variety of working dynamics and perception of environmental factors.



➢ **The aim of this study:** explore the linkage between the user age, gender, and season of the year and the changes in user metabolic rate

2. Methodology

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Fig. 1a. Building A

Public company building in Zagreb

Fig. 1b. Building B

Table 2.

		Gender		Age		
Examined facility	**Total**	**Men**	**Women**	**1. group 35-44**	**2. group 45-54**	**3. group 55+**
Building A	4	1	3	3	0	1
Building B	4	2	2	2	2	0

- 7-days monitoring, four times during the year in heating and cooling period

2. Methodology

➢ **Measurements protocol:**

Table 3. Measurements periods for buildings A and B

Measurement period	Building A	Building B
1. measurement	April 24 – May 04, 2018	May 22 – May 29, 2018
2. measurement	September 04 – September 14, 2018	July 03 – July 13, 2018.
3. measurement	November 06 – November 16, 2018	December 04 – December 14, 2018
4. measurement	January 29 – February 08, 2019	January 08– January 18, 2019.

➢ **Users' survey protocol:**

- Users reported thermal sensation 3 times during the day.
- Statistical analysis was performed using the IBM SPSS Statistic, statistical software, to determine the significance of the tested variables (age, gender, a season of the year) on the dynamics of metabolic rate.

2. Methodology

➢ Sensing device “Move 3”:

- The sensor recorded the raw data of 3D acceleration, barometric air pressure and temperature in a 1-minute time interval.
- From these data, the metabolic rate of each occupant was calculated with the “Movisens Data Analyzer” software.
- The sensors were fixed with a clip at the user's hip during their 8-hour working day

Fig.2. Triaxial accelerometer for activity recognition, Move 3

3. Results and discussion

➢Gender difference in metabolic rate:

- According to independent t-test, there is no statistically significant difference between the mean metabolic rate in the working day between males and females in this research study
- useful tool to track user activities during a working day

Table 4. **Group Statistics**

Gender		N	Mean	Std. Deviation	Std. Error Mean
Mean MET	Male	12	1,3833	,07177	,02072
	Female	20	1,4350	,10400	,02325

Table 5. **Independent Samples Test**

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Mean MET	Eq.v.* assumed	1,736	,198	-1,514	30	,141	-,05167	,03413
	Eq.v. not assumed			-1,659	29,274	,108	-,05167	,03115

3. Results and discussion

➢ User age difference in metabolic rate :

According to the Kruskal Wallis test, there is a statistically significant difference between building occupants of different age. There is only 0,1% chance that this difference in metabolic rates is due to chance.

Table 6. **Ranks**

Age		N	Mean Rank
Mean MET	1st age group	20	18,35
	2nd age group	8	6,50
	3rd age group	4	27,25
	Total	32	

Table 7. **Test Statistics**

	Mean MET
Chi-Square	15,122
df	2
Asymp. Sig.	,001

➢Impact of cooling/heating on metabolic rate :

- According to independent t-test, four out of eight study participants have different energy expenditure as a consequence of altered metabolic rate due to the season of the year.
- This result should be tested with a larger number of participants to investigate why this applies for some building occupants, and other does not.

3. Results and discussion

➢Characteristics of individual groups:

- Conducted measurement of dynamic metabolic rate during an 8-hour working day, showed a correlation for some of the building occupants

- According to this acknowledgment, users are categorized into 3 groups conforming to similar metabolic rate trends and personal characteristics. In addition, reported user responses are taken into consideration.

Table 8.

	Thermal comfort according to metabolic rates				Description
	Hot [MET]	Warm [MET]	Neutral [MET]	Cold [MET]	
Group 1	> 2.3	1.7 – 2.3	1.4 – 1.7	Not recorded	1st age group, higher temperature acceptance range, mostly females
Group 2	> 2	1.9 – 2	1.5 – 1.9	Not recorded	1st age group, Higher activity level, mostly males
Group 3	> 1.8	1.5 – 1.8	1.3 – 1.5	< 1.3	2nd and 3rd age group, narrow comfort range people with high BMI

4. Conclusions

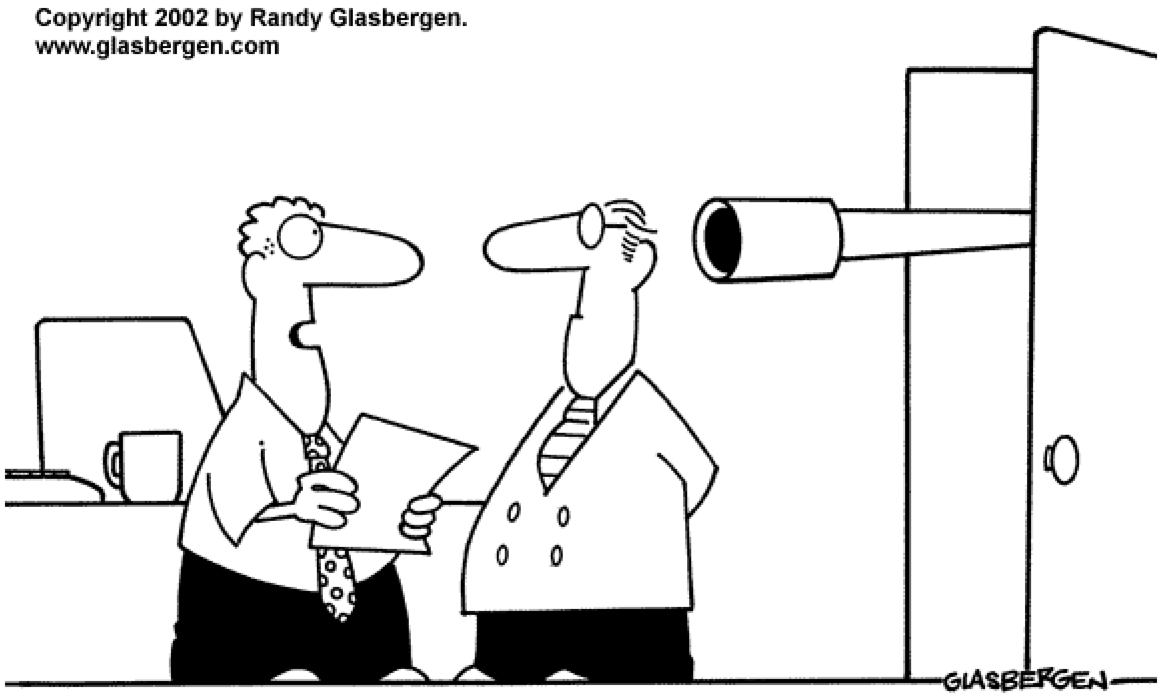
•The results show that there is no statistically significant difference between the mean metabolic rate in the working day between males and females. However, according to the Kruskal Wallis test, there is a statistically significant difference between building occupants of different age. According to independent t-test, four out of eight study participants have different energy expenditure as a consequence of altered metabolic rate due to the season of the year.

- The collected data was used to analyze the occupants' thermal preferences to prepare the model creation base

➢ Future research:

- develop personal comfort models to predict individuals' thermal preference
- model validation
- develop the logic of control regulation algorithms fitted for specific occupant profiles, taking into account the individual approach as well as the various possible circumstances in the office premises

Thank you for your attention!



"We need to reach an agreement on the thermostat settings.
The cold people have declared war on the hot people!"