

# Analysis of temperature difference on the total of energy expenditure during static bicycle exercise

**Sugiono\***

Industrial Engineering Department, Univeristas Brawijaya (UB), Indonesia

\*Corresponding author: [lsugiono\\_ub@ub.ac.id](mailto:lsugiono_ub@ub.ac.id)

**Abstract.** How to manage energy expenditure for cyclist is very crucial part to achieve a good performance. As the tropical situation, the differences of temperature level might be contributed in energy expenditure and durability. The aim of the paper is to estimate and to analysis the configuration of energy expenditure for static cycling activity based on heart rate value in room with air conditioning (AC)/no AC treatment. The research is started with study literatures of climate factors, temperature impact on human body, and definition of energy expenditure. The next step is design the experiment for 5 participants in 2 difference models for 26.80C – 74 % relative humidity (room no AC) and 23,80C – 54.8 % relative humidity (room with AC). The participants' heart rate and blood pressure are measured in rest condition and in cycling condition to know the impact of difference temperature in energy expenditure profile. According to the experiment results, the reducing of the temperature has significantly impact on the decreasing of energy expenditure at average 0.3 Kcal/minute for all 5 performers. Finally, the research shows that climate condition (temperature and relative humidity) are very important factors to manage and to reach a higher performance of cycling sport.

**Keywords:** energy expenditure, climate factors, static bicycle, hearth rate

## 1. Introduction

Bicycling is growing in popularity both as a form of transportation and for recreation in Indonesia. Many people start to realize the importance of sport and leisure in keeping and increasing human healthy. It is widely acknowledged that cycling is one of the cheapest and the best ways for people to achieve good health and fitness. People who cycle regularly could be live longer and stronger than those who do not exercise by bicycle. Moreover, the cycling facilities, participants and industry can be a significant driver of and contributor to Indonesian local economies. Based on the research before, bicycling gave tangible positive outcomes for economic, social, climate change and healthy lives [1]. These researches typically include categories such as industry (which includes manufacturing, sales and repair) and tourism. The some advantages of bicycling sport are: build strength muscle, increasing stamina, improves cardio-vascular fitness, eats up calories, improves heart health, improves human body coordination, and reducing stress [2].

According to explanation above, it can be concluded that bicycling is very popular for Indonesian community for doing sport and for recreation. Hence, it is reasonable that the activity should be conducted to physical workload and physiological condition. Level of heart rate (LHR) will be used to evaluate and to monitor the cyclist during their activity in order to keep in highest performance. The normal people generally has rest hearth rate at averages 60 to 80 beats per minute and for highly trained endurance athletes has as low as 30 bpm [3]. Bedny Z. Gregory and friends in their paper of “A heart rate evaluation approach to determine cost-effectives an ergonomics intervention” noted that



the total amount of heart rate is not exceed than 100 bpm and 4.17 kcal/min [4]. The average of LHR more than 100 bpm requires additional break time. When studying dynamic physical work, heart rate is the most informative measure for evaluating physical workload and environmental stress [4].

The importance of the hearth rate information can be used for managing the energy expenditure during bicycling activity. Ergonomics intervention is suitable for solving the problem. Knowledge of the metabolic rate is required to assess the working practices, energy cost of specific jobs or sport activities, and the total energy cost of an activity. As long as cyclist can control their heart rate or energy spend are not exceed than 100bpm or 4,17 kcal/ min, the top performance and the durability will be achieved [5]. Controlling and monitoring the energy expenditure are not easy for scientist. There are many factors influence in the problems e.g. body posture, human healthy, age, weight, climate (temperature, relative humidity), track, etc. The research will be focused on the impact of temperature in bicycling activity correlated in managing the energy expenditure. Static bicycle with difference workload will be applied in the experiment. In sort, the purpose of the paper is to investigate the difference impact of energy expenditure for cyclist in load variably. As a result, top performance and durability for the activity can be managed easily.

## 2. Experimental Methods

### 2.1. Research Materials

Cycling is one of human activity that correlated with muscular effort, work physiology and anthropometry. It is called a physical ergonomics which affected the capabilities of worker (human) to create an efficient job. A lot of thinks to study the physical ergonomics, such as: metabolism, heart rate, blood pressure, respiratory system (VO<sub>2</sub>), energy expenditure etc. To study the worker's performance based on the physical ergonomics is very complex which influenced by human posture, mental, habit and food consumption.

A lot of research used energy expenditure to measure the human performance in many goals as sports, health and recovery. The British Nutrition Foundation (BNF) defined an energy expenditure as the total of the basal metabolic rate (the amount of energy expended while at complete rest), the thermal effect of food (TEF, the energy required to digest and absorb food) and the energy expended in physical activity. Energy expenditure is proportional to hearth rate and VO<sub>2</sub> in doing activities [6]. There are two kinds of measurement the energy expenditure for direct and indirect calorimetric. Direct calorimetry (metabolic chamber) is determined by calculating the production of heat by the body. On the other hand, indirect calorimetry is determined by employed VO<sub>2</sub> during rest and activity. Oxygen consumption is considered as the standard for measuring the physiological intensity of exercise. The maximal oxygen uptake (VO<sub>2</sub>max) is important in that it is generally considered the main factor of the aerobic fitness of a cyclist. VO<sub>2</sub> and energy expenditure are calculated for athletics, workers hospitals to determine the capability of the body to perform work, to measure the efficiency of performing various activities. In this case, the efficiency is defined as work done divide energy used.

Recent studies have shown that heart rate can successfully be used as a proxy for the measurement of rate of oxygen consumption or metabolic [7]. The heart rate investigation such as measurement of oxygen consumption (VO<sub>2</sub>max) needs special technical knowledge, skill and sophisticated instrumental setup. It becomes difficult to determine the oxygen consumption of a human with limited resources. As consequence, many researches exploit the relationship among heart rate, blood pressure and O<sub>2</sub> consumption. According to the journal noted that the VO<sub>2</sub>max can be calculated as formula 1 bellow [8]:

$$VO_{2max} = 15 \frac{mliter}{Kg.minute} \times \frac{HR_{max}}{HR_{rest}}$$

Where: VO<sub>2max</sub> = Maximum oxygen consumption (mliter)

HR<sub>max</sub> = maximum heart rate (bpm)

HR<sub>rest</sub> = Heart rate in rest condition (bpm)

## 2.2. Experiment Design

According to the aim of the research as mentioned before, the research will investigate the correlation between differences of the environment temperatures and the energy expenditure in cycling activity. The research used a static bicycle to test the correlation for five male cyclists. Table 1 show personal details for five participants included age, weight and height. The data is used to determine the total of energy expenditure during activity based on heart rate and VO<sub>2</sub>.

**Table 1: List data of five personal cyclists**

No	Participant	Age	Weight	Height
1	Participant 1	22 years	175 cm	78 Kg
2	Participant 2	21 years	153 cm	44 Kg
3	Participant 3	22 years	176 cm	70 Kg
4	Participant 4	21 years	171 cm	71 Kg
5	Participant 5	20 years	161 cm	65 Kg

Following is the steps for doing the research to know the impact of difference temperature in cycling activity. The difference temperature is created by using air conditioning (AC) and without air conditioning (no-AC). To do the test, two days experiment have been done for the first day for test in normal environment condition with T = and RH = (no AC) and the second day for test in design environment condition with T = 23.8°C, RH = 54.8 % (AC). The steps of the research for the first day are:

- Measuring heart rate and blood pressure for all participants in the rest condition without air conditioning (no-AC). The participants have the same treatment before do the test which having breakfast 4 hours before cycling with the same menu.
- Warming up using static bicycle with the same speed and workload in 4 minute.
- Measuring heart rate and blood pressure for all participants each minute for 5 minute cycling in no AC condition.

The steps of the research for the second day (using AC) are:

- Designing the environment condition for AC until steady condition which having same condition of air quality, temperature and relative humidity.
- Measuring heart rate and blood pressure for all participants in rest condition with air conditioning. The participants have the same treatment before do the test which having breakfast 4 hours before cycling with the same menu.
- Warming up using static bicycle with the same speed and workload in 4 minute.
- Measuring heart rate and blood pressure for all participants each minute for 5 minute cycling in no AC condition.

## 3. Results and Discussion

Measuring heart rate and blood pressure are used to analysis the demand of energy expenditure correlated with difference of environment temperature. Figure 1 explains the comparison of heart rate for five participants in no AC and environment with AC condition. It can be concluded that by using AC, it will increase the average of heart rate for participant from 86.6 bpm to 90.26 bpm or 4.2 %.

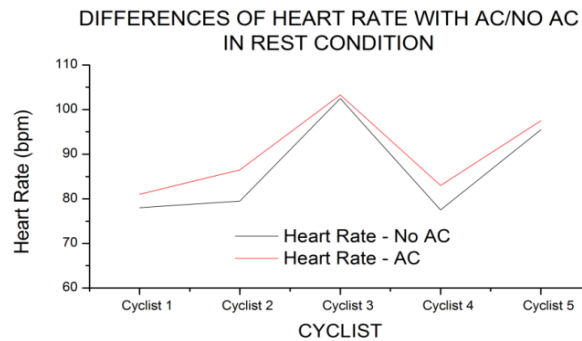


Fig. 1. Heart rate comparison for participants in rest condition with AC and without AC

Figure 2 explains the comparison of blood pressure systolic/diastolic for five participants in no AC and environment with AC condition. It can be concluded that AC increased the average of blood pressure systolic for participant from 123.6 mmHg to 137.4 mmHg or 11.2 % and from 71.8 mmHg to 81.4 mmHg or 13.4 % for diastolic. It can be declared that AC in rest condition will increase the blood pressure for participants (cyclist) with average age 21.2 years old, weight 65.6 Kg and height 167.2 cm. Subjectively, participants in tropical condition will not enjoy in the low environment temperature as indicated by increasing both of blood pressure and heart rate.

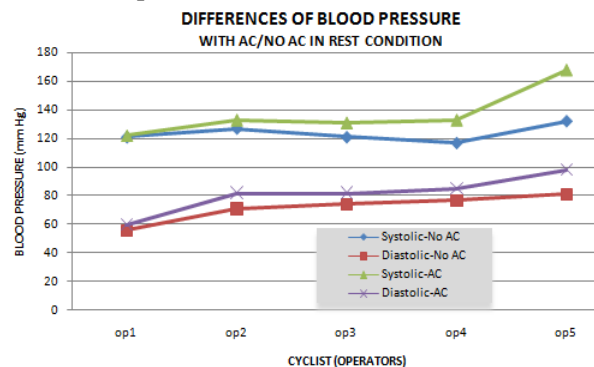


Fig.2. Blood pressure comparison for participants in rest condition with AC and without AC

Figure 3 explains the comparison of heart rate for five participants in cycling condition with AC/no AC condition. It can be concluded that AC decreased the average of heart rate for participant from 111.2 bpm to 107.7 bpm or 3.1 %. It can be declared that generally AC in working (cycling) condition will decrease the heart rate for participants (cyclist). Except, the participant 5 was still has higher heart rate in AC condition than in no AC with delta heart rate = 2.7 bpm.

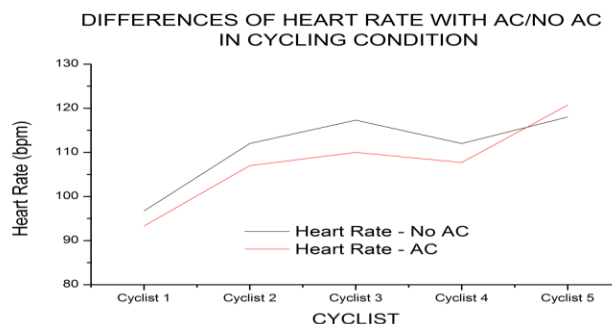


Fig.3. Heart rate comparison for participants in cycling condition with AC and without AC

Figure 4 explains the comparison of blood pressure systolic/diastolic for five participants in cycling activity with AC/ no AC condition. It can be concluded that AC decreased the average of systolic-blood pressure for participant from 134.2 mmHg to 128.9 mmHg or 4.0 % and from 79.1 mmHg to 73.6 mmHg or 7.0 % for diastolic. It can be declared that AC in working (cycling) condition will decrease the blood pressure for participants (cyclist).

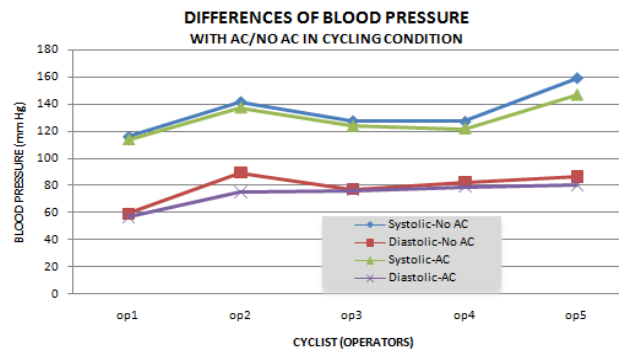


Figure 4. Blood pressure comparison for participants in cycling condition with AC and without AC

The total of physical energy expenditure is calculated by multiply the amount of O<sub>2</sub> intake (VO<sub>2</sub>) with 4.8 Kcal/minute [5]. The VO<sub>2</sub> can be calculated by equation 1, as example the participant 3 with average heart rate for working (6 minute in cycling) = 117.3 bpm, heart rate for rest = 102.5 bpm age = 21 years old, weight = 70 Kg, height = 171 cm cycling in no AC condition will need VO<sub>2</sub>:

$$\begin{aligned}
 VO_2 &= \frac{15 \text{ mliter}}{\text{Kg} \times \text{minute}} \times \frac{117.3}{102.5} \\
 &= \frac{15 \times 70 \times 6 \text{ mliter}}{1} \times \frac{117.3}{102.5} \\
 &= 1.20 \text{ Liter/minute}
 \end{aligned}$$

As a result, the participant 3 spend the energy expenditure = 1.20 liter/minute x 4.8 kcal/liter or 5.76 kcal per minute for static cycling test. Figure 5 shows the differences of energy expenditure for all cyclists in AC and no AC condition. From the graph, it can be inferred that energy expenditure for cyclists in AC condition needs less energy than cyclists in non AC condition.

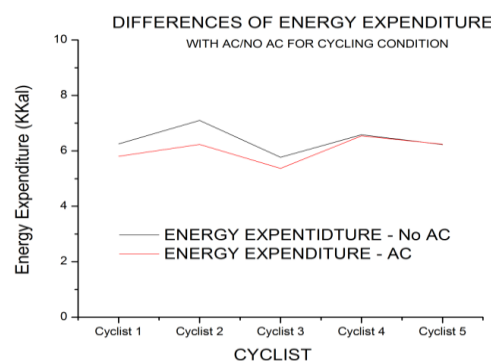


Fig.5. Difference of the total of energy expenditure for cyclists in AC and no AC

#### 4. Conclusions

The research has successfully presented the correlation of heart rate/ blood pressure, human activity, energy expenditure and environment condition (temperature and relative humidity) in tropical condition. According to 5 participants, low temperature (using AC) will generally increase the heart rate/ blood pressure in rest condition. Whereas, the AC condition (cooling room) gave less heart rate than no AC condition in static cycling test. As consequence, the total amount of energy expenditure for cycling test in AC condition is less than in no AC condition. In sort, lower temperature is a benefit for cyclists and it can help them to manage and to keep more energy in their body.

#### Acknowledgment

Thanks to the Ministry of National Education of the Republic of Indonesia for supporting this paper. The authors are also grateful to the laboratory of work design and ergonomics, Industrial Engineering Department, the University of Brawijaya (UB), Malang Indonesia for their extraordinary courage.

#### References

- [1] Cavill N, Davis A., "Cycling and Health: what's the evidence?". Cycling England, 2007.
- [2] Rojas-Rueda D, de Nazelle A, Tainio M, Nieuwenhuijsen MJ, 2011. "The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study", British Medical Journal BMJ 2011; 343:d4521
- [3] de Hartog JJ, Boogaard H, Nijland H, Hoek G, 2010. Do the health benefits of cycling outweigh the risks?. Environmental Health Perspectives
- [4] Bedny Z.Gregory, Karwowski Waldemar, Seglin H. Mark, "A heart rate evaluation approach to determine cost-effectives an ergonomics intervention", International Journal Of Occupational Safety And Ergonomics 2001, Vol. 7, No. 2, 121–133.
- [5] Mikell P. Groover, "Work Systems and the Methods, Measurement, and Management of Work", Pearson Education, Inc., 2007.
- [6] Akihiko Tajima, "Assessment of energy expenditure: an association between heart rate and oxygen uptake in daily physical activity" International Journal of Analytical Bio-Science, Vo.2, No.4 (2014)
- [7] Sanchita Ghosha, Rauf Iqbalb, Amitabha Dec and Debamalya Banerjeed, "Relationship of Heart Rate with Oxygen Consumption of adult male workers from Service and Manufacturing Sectors", International Journal of Physical Education, Fitness and Sports Vol.3.No.3 | September'2014.
- [8] Uth, Niels; Henrik Sørensen; Kristian Overgaard; Preben K. Pedersen (January 2004). "Estimation of VO2max from the ratio between HRmax and HRrest--the Heart Rate Ratio Method". *Eur J Appl Physiol.* 91 (1): 111–5