



## Effect of Relative Humidity on Expenditure of Body Fluids and Blood Pressure when Exercise



I Nengah Sandi <sup>a</sup>  
AA Gede Ardana <sup>b</sup>  
I Made Yoga Parwata <sup>c</sup>  
I Wayan Teresna <sup>d</sup>

### Article history:

Received: 9 July 2016

Accepted: 30 January 2017

Published: 31 March 2017

### Keywords:

*body fluids;*  
*diastolic blood pressure;*  
*expenditure;*  
*relative humidity;*  
*systolic blood pressure;*

### Abstract

Physical exercise is prolonged at high relative humidity can lead to an increase in expenditure of body fluids (EBF) through perspiration. Excessive discharge can cause changes in body functions such as blood pressure changes in practice. Objective: This study aimed to prove that the relative humidity (RH) 40% inhibiting EBF and does not inhibit the increase in systolic blood pressure (SBP) and diastolic blood pressure (DBP) after physical exercise during 2X30 minutes. In addition, it also to prove physical exercise can improve exercise SBP and DBP. The study was conducted on 51 male students Faculty of Physical Education and Health, IKIP PGRI Bali. The samples were divided into three groups, and each group was given a different treatment. Group-1 exercise on the RH of 40%, Group-2 at the 50% RH, and the Group-3 at the RH of 60%. Data EBF, SBP, and DBP are measured before and after treatment. The mean difference EBF, SBP, and DBP between before with after treatment in all groups increased significantly ( $p < 0.05$ ). The mean EBF after treatment was significantly different between groups with  $p = 0.009$  and significant differences occurred between group-1 with the Group-3 with  $p = 0.002$  ( $p < 0.05$ ). Average SBP and DBP after treatment was not significantly different between groups with consecutive values  $p = 0.729$  and  $p = 0.562$  ( $p > 0.05$ ). Thus, physical exercise can improve the EBF, SBP, and DBP. RH of 40% can inhibit the EBF and can't inhibit an increase in SBP and DBP. Thus, if practiced in a long time expected to be made on the RH of 40% because it can inhibit the EBF.

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### Author correspondence:

I Nengah Sandi,  
Master of Sports Physiology, University of Udayana, Bali, Indonesia  
Email address: [sandinengah@yahoo.com](mailto:sandinengah@yahoo.com)

<sup>a</sup> University of Udayana, Indonesia

<sup>b</sup> IKIP PGRI Bali, Indonesia

<sup>c</sup> IKIP PGRI Bali, Indonesia

<sup>d</sup> State Polytechnic of Bali, Indonesia

## 1. Introduction

Temperature and relative humidity are physical environmental factors are very important to note, either at work or during sports. Temperature and high humidity can affect physical performance, namely a decrease in performance. In addition to temperature and RH, other factors also affect the appearance is the altitude, wind speed, and lighting (Birch *et al.*, 2005; Powers & Howley, 2009).

RH is high can cause heat stress and several other health problems. Physical exercise at high humidity and high temperatures also will be more dangerous if done without sufficient airflow. As the exercises conducted in a closed room is not equipped with an air conditioning system (Giriwijoyo, 2007).

Physiological changes occur due to an increase in EBF as a result of heat loss through sweat (Cameron, 2012). The results of previous research, aerobic exercise for long periods can increase the EBF. If not matched by consuming enough fluids, will complicate the heat emitting body (Cheuvront, *et al.*, 2010). The difficulty of body heat expenditure due to an increase in blood viscosity which inhibits heat loss through convection (Wilmore *et al.*, 2008). Increased blood viscosity will increase the SBP and DBP (Irawati, 2010; Gabriel, 2012).

EBL excess will increase the SBP, DBP, and pulse rate (Gawron, 2008). The results of previous studies, EBL directly related to blood pressure (BP), in which an increase in BP on improving the EBF (Cianci *et al.*, 2006). An increase in SBP of 120 mmHg to 250 mmHg in endurance exercise with maximum intensity (Kusnanik *et al.*, 2011). Furthermore, prolonged exercise in a confined space will increase blood pressure, both SBP, and DBP. Increased BP is caused the body loses a lot of fluid to dissipate heat to the body surface (WHO, 2011).

In addition to increasing the BP and improve the EBF, exercise at high RH also lead to an increase of the pulse rate, body temperature, and blood lactic acid concentrations. A previous study of the 51 students, obtained RH of 40% inhibits the increase in pulse rate, blood lactic acid, and a body temperature of exercise (Sandi, 2016). Previous results obtained, increased body temperature of 37 °C reached 40 °C, when a prolonged physical exercise in the hot and humid environment (Gonzalez-Alonso *et al.*, 1999). At a relative humidity of 80%, an increase in body temperature with a humidity of 59% compared to the nine subjects after exercise by cycling for two hours (Saunders, *et al.*, 2005). Also obtained through research, increased concentrations of blood lactic acid after exercise between before the bench press exercise (Bloomer & Cole, 2009). EBF speed will decrease the volume of body fluids, which will accelerate the increase in blood lactic acid concentrations (Janssen, 1993). EBF excess will reduce the concentration of O<sub>2</sub> in blood so that glycolysis in the liver will decrease and followed by an increase in blood lactic acid concentrations (Kusnanik *et al.*, 2011).

Low air RH will speed up the body heat transfer to the environment through evaporation. Furthermore, a low-temperature environment which will accelerate the transfer of body heat to the environment through radiation and convection (Gabriel, 2012; Sandi, 2014). Low RH will accelerate the heat emitting body so that body heat remains in normal circumstances. Body heat within normal limits, the athlete will still feel comfortable during exercise and no harm (Giriwijoyo, 2007).

Therefore, physical exercise for a long time requires high temperature and RH comfortable environment. Comfortable temperatures are between 18-30 °C and RH between 40-60%. This is in line with the Regulation of the Minister of Health of the Republic of Indonesia No: 1077/Menkes /Per/V/2011 (Health Ministerial of Republic of Indonesia, 2011).

## 2. Materials and Methods

This study design was Pre - Post Test Control Group Design (Pocock, 2008). Fifty-one subjects were divided into three groups, where each group numbered 17 people. All subjects were given a cycling exercise using Technogym bicycles New Bike EXC 700. Group-1 was cycling at 40% RH, Group-2 at 50% RH, and Group-3 at 60% RH. EBF, SBP, and DBP in each group were observed before and after treatment.

Thirty minutes before exercise, all subjects were given mineral water to drink as much as 240 mL. In addition, it also confirmed the subject has urinated before weighing, followed by the measurement of SBP and DBP. After the blood pressure measurement, the subjects warmed up for 10 minutes, beginning with stretching. Final warm-up done is ride a stationary bike for five minutes until it reaches the pulse rate of 120 beats per minute at level two and level three. At the core exercises, the workload increased by 80 Watt ie frequency 71 strokes per minute at level four. Exercise with a constant load is done for 2X30 minutes with breaks between sets for five minutes. SBP and DBP

exercise measured at the 30<sup>th</sup> minute of the second set that is before cooling when the subject was still on the bike. Weight gain after treatment was measured after the subject of cooling and sweat has dried ascertained.

EBF is determined by weighing before and after treatment with ACIS digital scales with a precision of 0.01 kg. Then calculate the difference between the weight before after treatment. EBF in milliliters converted from weight loss as a result of the expenditure of body fluids through sweating. SBP and DBP measured using digital sphygmomanometer with a precision of 0.0 mm Hg.

Data were analyzed by Shapiro-Wilk normality test and continued by homogeneity test with the Levene's test. The difference between the data before to the after treatment were tested by t-test paired while Oneway ANOVA test is used to test for differences between groups of data. The use of this test because all data were normally distributed and homogeneous. To test for differences between each group used the Least Significant Difference (LSD).

### 3. Results and Discussions

#### 3.1 Result

##### *Characteristics of Research Subjects*

Characteristics of the subjects of this study were age, body mass index (BMI), resting pulse rate (RPR) and physical fitness (PF). PF measured by the time you've run 2.4 km which is expressed in minutes.

Table 1  
Characteristics of research subjects

Characteristics	Mean $\pm$ SD		
	Group-1	Group-2	Group-3
Age (year)	20,17 $\pm$ 0,70	20,60 $\pm$ 1,38	20,57 $\pm$ 0,68
BMI (kg/m <sup>2</sup> )	22,59 $\pm$ 1,91	21,85 $\pm$ 2,25	21,28 $\pm$ 2,24
RPR (b/m)	84,88 $\pm$ 8,73	80,88 $\pm$ 11,60	78,06 $\pm$ 12,95
PF (mt)	12,87 $\pm$ 0,85	12,60 $\pm$ 0,97	12,72 $\pm$ 1,02
- good (%)	11,80	11,80	17,60
- fairly (%)	88,20	88,20	82,40

Description: SD = standard deviations, kg/m<sup>2</sup> = kilograms per square meter, b/m = beats per minute

##### *Test of Normality and Homogeneity Data*

To determine which test is used then tested with the Shapiro-Wilk normality test and homogeneity test with Levene's test. Data is tested EBF, SBP, and DBP both before and after treatment.

Table 2  
The result of Normality and Homogeneity Test

Variable	p-value (Normality)			p-value (Homogeneity)
	Group-1	Group-2	Group-3	
EBF	0,692	0,062	0,775	0,961
SBP Before	0,520	0,525	0,928	0,823
DBP After	0,510	0,383	0,706	0,126
SBP Before	0,708	0,843	0,850	0,490
DBP After	0,813	0,421	0,186	0,943

Description: p = probability

##### *The Mean Difference Blood Pressure between Before with After Treatment*

Differences of SBP and DBP between before with after treatment in all groups were analyzed by paired t-test. Statistical test results are presented in Table 3.

Table 3  
Differences of SBP and DBP between before with after treatment

Variable	Mean $\pm$ SD		mean difference	p-value
	Before Treatment	After Treatment		
SBP Group-1	127,82 $\pm$ 6,25	153,94 $\pm$ 10,23	-30,12	0,000
DBP Group-1	73,12 $\pm$ 8,45	79,06 $\pm$ 6,78	-5,94	0,012
SBP Group-2	126,82 $\pm$ 6,35	153,29 $\pm$ 7,65	-26,47	0,000
DBP Group-2	72,77 $\pm$ 9,49	79,65 $\pm$ 7,00	-6,88	0,004
SBP Group-3	124,59 $\pm$ 7,00	155,65 $\pm$ 8,57	-31,06	0,000
DBP Group-3	68,06 $\pm$ 5,74	77,24 $\pm$ 6,58	-9,18	0,000

Description: p = probability, SD = standard deviations

#### Differences of Treatment Results between Groups

Differences of EBF, SBP, and DBP between group before and after treatment were tested by One-Way ANOVA (Table 4).

Table 4  
Results of Difference Test EBF and Blood Pressure between groups

Variable	Mean $\pm$ SD			p-value
	Group-1	Group-2	Group-3	
EBF	582,35 $\pm$ 139,13	635,29 $\pm$ 108,63	688,24 $\pm$ 137,53	0,009
SBP Before	127,82 $\pm$ 6,25	126,82 $\pm$ 6,35	124,59 $\pm$ 7,00	0,344
DBP After	73,12 $\pm$ 8,50	72,77 $\pm$ 9,49	68,06 $\pm$ 5,74	0,136
SBP Before	153,94 $\pm$ 10,23	153,29 $\pm$ 7,65	155,65 $\pm$ 8,57	0,729
DBP After	79,06 $\pm$ 6,78	79,65 $\pm$ 7,00	77,24 $\pm$ 6,58	0,562

Description: p = probability, SD = standard deviations

The test results further using by LSD, differences of EBF between Group-1 with Group-2 is - 64.71 mL with p = 0.113, distinguish between Group-2 with Group-3 is - 64.71 mL with p = 0.113, and the differences between Group-1 with the Group-3 is - 129.41 mL with p = 0.002. So there is a significant difference between Groups-1 with Group-3 (p < 0.05).

### 3.2 Analysis

#### Characteristics of Research Subjects

In Table 1, mean age of Group-1, Group-2, and Group-3 was in the range between 18-25 years. At the age of a college, because after graduating high school subjects aged 18 years and in the last semester of college mean age was 22-25 years. Age-related to ability biometric component of which is muscle endurance, muscle strength, and others (Astrand & Rodahl, 2003).

Mean of BMI was in the normal range in the range of 18.5 to 24.9 kilograms per square meter in accordance with WHO standards (WHO, 2007). BMI showed nutrition status affects the appearance in the exercise. Results from previous studies of 33 students, BMI is obtained relating to RPR. Increasing BMI, the RPR is increasing, contrary RPR will decrease if the BMI decreased (Sandi, 2013).

Mean of RPR are in the normal range is between 60-90 beats per minute (Burke, 2001). RPR indicates the level of one's aerobic capacity because it can provide information about the physical condition. Increasing aerobic capacity that is done, then decreased RPR. Otherwise, RPR would increase if lowered aerobic capacity (Sandi, 2016).

Mean of PF as measured by the time you've run 2.4 km were in a good category until fairly, at Group 1, Group 2, and Group 3. The travel time to run 2.4 km ranged from 9.68 to 12.17 minutes for subjects aged under 20 years and between 10.75 to 14.00 for subjects aged over 20 years (Kuntaraf & Kuntaraf, 2009). PF difference in all groups was not much different. PF category either in each group respectively 11.80%, 11.80%, and 17.60%, while the rest are located in both categories. Thus PF research subjects are in the same predicament.

### *Normality and Homogeneity Data*

Dependent variable data in the form of EBF, SBP, and DBP in all groups of the normal distribution. EBF homogeneity test results showed after treatment has the same variant. Likewise with SBP and DBP both before treatment and after treatment is homogeneous. This is indicated by the value of  $p > 0.05$  (as shown in Table 2). Thus, the parametric test can be applied.

### *Treatment Effects of SBP and DBP*

Table 3 shows, an increase in SBP and DBP in each group, both exercising at 40% RH, 50% RH, and 60% RH. The difference in blood pressure between before and after treatment is indicated by the results of paired t-test with  $p < 0.05$ . From the mean difference in blood pressure increase, it appears that SBP increases higher than the DBP, both at Group-1, Group-2, and Group 3.

Any physical exercise will increase blood pressure. Research has been conducted on 28 patients with hypertension, found an increase in SBP or DBP (Cianci *et al.*, 2006). The results of another study of 16 students between the ages of 20-23 years, found an increase in SBP of 116.1 mmHg became 135.0 mmHg after physical activity squat-stand with a frequency of 60 times per minute for one minute (Cynthia, 2002).

Further stated, aerobic physical exercise with maximum intensity in people trained can increase SBP of 120 mmHg to 250 mmHg. Improvement will be higher if the exercise intensity increased. Increased blood pressure is caused by an increase in cardiac output. Anaerobic exercises involving large muscles will further increase blood pressure. This is due to the increased peripheral resistance of blood vessels, which is caused by the suppression of blood vessels by skeletal muscles when to contract (Kusnanik *et al.*, 2011; Sandi, 2014). The increase in blood pressure upon exercise will be visible when the body fluid has decreased by 2% as a result of transpiration (WHO, 2011).

### *Exchange Differences Treatment of EBF*

In Table 4, shows that there are differences between groups of EBF. EBF during exercise at an RH of 40% (Group-1) is lower than the RH of 50% (Group-2) and RH of 60% (Group 3) as indicated by the value of  $p < 0.05$ . Transpiration differences between Group 1 with Group 3 were higher than the Group-1 with Group 2 and between Group 2 with Group 3. Significant differences in volume transpiration occur only between Group 1 with the Group 3.

Various physiological changes of prolonged exercise in high RH may occur. This is because there is difference transpiration, in which the 40% RH sweat less. At high RH (Group 3), there will be an increase in expenditure of sweat to release body heat and even sweat it out until dripping (Gawron, 2008). Furthermore, it is stated that physical exercise for long periods will cause a loss of body fluids caused by the decrease of body fluids through sweat (Cameron, 2012).

This is supported, that transpiration is accelerated at high RH and decreased at a low RH (Sandi, 2013; Darwis *et al.*, 2007). These results indicated by the EBF differences between Group 1 with Group 2, between group 2 with Group 3, and between Group 1 with the Group 3.

EBF difference occurs only between workouts at 40% RH with 60% RH. This is likely due to differences in RH by 20% between Group 1 with Group 3 was able to show the difference of the EBF. While the Group-1 with Group 2, and between Group 2 with Group 3 RH difference of 10% has not been able to show any differences EBF.

### *Differences in the Treatment of SBP Securities and DBP*

Table 3 shows that SBP and DBP before treatment are in the normal range. The normal range of SBP is below 130 mmHg and DBP are under 85 mmHg (Divine, 2012). Mean difference of SBP and DBP before treatment did not differ significantly ( $p > 0.05$ ). This means that if there is a difference after treatment, it is caused by the treatment given. Mean of SBP and DBP after the treatment was not significant ( $p > 0.05$ ). This means that there is no difference in the effect of RH to SBP and DBP at practice. This is supported, that BP increases with increasing intensity of the workout (Sandi, 2014). BP Improvement is needed because of the current training needs of blood that transports nutrients and  $O_2$  to active parts of the body increases. SBP and DBP at practice did not continue to increase as controlled by the baroreceptor system and mechanism that reacts central nerve system (CNS) ischemia ranging from a few seconds to 30 seconds. In addition to the baroreceptor system and mechanisms of CNS ischemia, blood pressure is also controlled by the capillary fluid shift mechanism (Sandi, 2014).

No differences in SBP and DBP between groups of exercise due to higher RH will be an increased sweating. Increase transpiration, causing an increase in blood viscosity. Increased blood viscosity will increase body temperature which causes vasodilation of blood vessels. Otherwise, every  $1^\circ C$  increase in body temperature will be followed by a decrease in blood viscosity as much as 2%.<sup>7</sup> In addition, also due to the increase in body temperature can cause dilation of blood vessels. Dilation of blood vessels to increase blood flow effect, that any increase in the diameter of blood

vessels as much as two-fold, to be followed by an increase in blood flow as much as 16 times (Hall, 2016). Thus, exercise at high humidity can't increase blood pressure. The results showed that 40% RH inhibiting EBF during exercise compared with 50% RH and 60% RH, but did not inhibit the increase in SBP and DBP. Lower EBF that came out during the exercise will be more beneficial to the athlete's body functions. Therefore, the 40% RH is said to inhibit the EBF and can't inhibit an increase in SBP and DBP at practice.

#### 4. Conclusion

Physical activity can increase spending EBF, SBP, and DBP. RH of 40% can inhibit the decrease in EBF ( $p < 0.05$ ) and can't inhibit an increase in SBP and DBP ( $p > 0.05$ ). Therefore, when practiced over time in a closed room expected at 40% RH.

#### *Conflict of interest statement and funding sources*

The author(s) declared that (s)he/they have no competing interest. The study was financed by the authors.

#### *Statement of authorship*

The author(s) have a responsibility for the conception and design of the study. The author(s) have approved the final article.

#### *Acknowledgments*

My deep and sincere gratitude were presented to God for having granted me the ability and the opportunity to complete this paper. As well as, I have much appreciated to my friends for their support, suggestion, contribution in finishing this research. Last but not least, I dedicated my dreadful thank to my friend who those as editor in IJCU of International Journal.

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**Biography of Authors**

	<p>Dr. I Nengah Sandi, S.Si, M.FOr was born on December 31<sup>th</sup>, 1966 in Banjar Selati, Desa Bunutin-Bangli. After graduating from the Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University - Indonesia in 1995, I worked at the temporary teacher at the School of Technology Secondary Saraswati Denpasar until 2000. In 2000 was appointed as a lecturer in the Section of Basic Medical Sciences, Faculty of Medicine Udayana University. Afterward continued his education at Master in Sports Physiology, Udayana University. In 2008 is set as a lecturer in Sports Physiology.</p> <p><i>Email: <a href="mailto:sandinengah@yahoo.com">sandinengah@yahoo.com</a></i></p>
	<p>Drs. A. A. Gede Ardana, M.FOr A senior lecturer in the Faculty of Physical Education and Health, IKIP PGRI Bali – Indonesia.</p>
	<p>Dr. I Made Yoga Parwata, S.Pd, M.Kes A lecturer in the Faculty of Physical Education and Health, IKIP PGRI Bali – Indonesia.</p>
	<p>I Wayan Teresna, S.Si, M.FOr A senior lecturer in the State Polytechnic of Bali - Indonesia</p>