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Original Article

Both upper and lower extremity-only video game-based exercises (exergaming) affect blood glucose serum levels and heart rates but not oxygen saturation in teenagers

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Abstract:
A decrease in the frequency of physical activities is apparent in children and adolescents. This is partly due to their fondness for playing games on gadgets. If the decline in physical activity continues, it is feared that it may indirectly increase the prevalence of metabolic diseases, such as obesity, heart disease, and diabetes mellitus. One of the newest innovations to make exercise easier is video game-based exercises (exergaming). Via exergaming, exercises can be done while sitting down (only the upper extremities are moving) or by standing up in a person's own comfortable space. Therefore, this study aimed to determine the effect of performing exergaming via only the upper and lower extremities on blood glucose (BG), heart rate (HR), and oxygen saturation levels. The participants (± 20 year old) were college students, including 24 boys who were divided into three groups, a control group, an upper extremities exergaming (upperEx) group, and a lower extremities exergaming (lowerEx) group. The participants performed mild to moderate intensity exergaming for approximately 30 min. The variables studied included the BG level, HR, and the percentage of oxygen saturation (SpO_2). The serial time for collecting data included fasting, 30 min (30'), 60' (after exercise), 90', and 120' after drinking a sweet solution. The results showed that there was a significant difference between the control and treatment groups regarding the 60' BG level and the 60', 90', and 120' of HR with a slower increase in the upperEx. Nonetheless, percentage of SpO_2 did not differ among the groups. Therefore, we suggest that exercises of the upper and lower extremities have benefits for the health of teenagers. However, we assume that upper extremity-only exergaming is less harmful for a person who has metabolic disease.
Key Words: exergaming, glucose, heart rate, oxygen saturation, teenager

Introduction

Currently, physical activities done by children and adolescents are decreasing. In the adolescent period, physical activities decline around 7% per year, resulting in the global physical activity change among adolescence of around 60–70% (Dumith, Gigante, Domingues, & Kohl-III, 2011). This condition is related to the increase of secondary activities such as playing games on the gadget or the non-supporting environment and condition. The declining physical activities give rise to several health issues as they may directly increase the prevalence of metabolic diseases such as obesity, heart disease, and diabetes mellitus. Based on a report by the World Obesity Federation (2018), the obesity prevalence of kids was around 13–15 years between 2001 and 2013. It has become one of the rising factors in the risk of metabolic diseases.

Diabetes mellitus is a medical condition caused by excessive blood glucose in the body. This is due to the inability of blood glucose to enter the cell as an energy source. Diabetes mellitus can be divided into two types. Type 1 diabetes is the inability of the body to produce adequate insulin, because the immune system destroys pancreatic beta cells called autoimmune. Meanwhile, type 2 diabetes is a condition where the body is unable to produce or use insulin properly or where insulin resistance occurs (American Diabetes Association, 2018).

Nowadays, diabetes mellitus has received more attention because of its drastically increasing prevalence. In 2013, there were 382 million people with diabetes mellitus, and 90% of the cases were type 2 diabetes. This is equal to 8.3% of the world's adult population. Also, in 2012 and 2013, diabetes mellitus killed 1.5 to 5.1 million people per year, which made diabetes mellitus the 8th cause of death in the world (Tao, Shi, &

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Zhao, 2015). Hyperglycemia for a long period, such that of diabetes, can cause deadly diseases. One of the diabetic preventions is doing physical activities (Routen, 2010; Yuliya & Sergey, 2018).

Many innovations make aerobic exercises more enjoyable; one of the examples is video-game-based exercises (exergaming). Exergaming is a "game" using console, which provides videos facilitating physical exercises. In this study, exergaming refers to the use of games which provide videos (using XBOX or Nintendo Wii). Using exergaming, exercises can done while sitting down (only upper extremities are moving) or by standing up. Exercises can be done in a comfortable room. However, the different effects of focusing only on upper and lower extremities on health parameters have not been clearly identified.The objective of this study is to determine the effect of upper and lower extremities exergaming on blood glucose (BG) level, heart rate (HR), and the percentage of oxygen saturation (SpO_2) as key parameters of health.

Material & methods

This study has been approved by the Medical Research Ethics Committee of Faculty of Medicine, Universitas Airlangga, Surabaya, East Java, Indonesia.

Participants

This study involved twenty four healthy participants (± 20 y.o, college students) who were divided randomly into 3 groups: control group, upper only extremities exergaming (upperEx) group, and lower only extremities exergaming (lowerEx) group.

Procedure and Instruments

All of the participants were instructed to fast for 8 hours. The fasting blood glucose (BG), heart rate (HR), and percentage of oxygen saturation (SpO_2) were measured. Then, sweet drink was given to all participants. After 30 minutes (30'), the 30' of BG, HR, and SpO_2 were obtained. After that, participants in the control group were instructed to stay (not doing physical activities), while participants in the upperEx and lowerEx groups did exergaming for about 30 minutes. Those in the UpperEx group exercised with their upper extremities dominantly and those in the lowerEx group exercised with their lower extremities dominantly.

After exergaming, some variables were measured immediately after exergaming (60), 90, and 120 minutes after having the sweet drink.

Blood glucose was measured using an Accucheck Performa glucometer. Heart rate and SpO_2 were determined using OxyOne Finger Pulse Oximeter.

Statistical analysis

Normality test was performed to determine the distribution of the data. Anova test was used when it was normally distributed. If the result of Anova test was significantly different, it would be followed by post-hoc test. Kruskal-wallis test was used if the distribution of the data was not normal. If the result of Kruskal wallis was significantly different, it would be tested by mann-whitney. Pearson or Spearman test was used to evaluate the correlation of the variables. The data were displayed in graphical figures and tables indicating the mean±standart of deviation.

This study has been approved by the Medical Research Ethics Committee of Faculty of Medicine, Universitas Airlangga, Surabaya, East Java, Indonesia.

Results

Prior to initiating the treatment, anthropometric variables, blood glucose levels, heart rates, and oxygen saturation conditions were measured (table 1.) to find out if the participants were homogeneous.

Table 1. Characteristic of the participants and the baseline data (before treatment)

Group	Age (y.o)	BMI (kg/m^2)	BG_f (mg/dL)	HR_f (bpm)	SpO_2_f (%)
control (n=8)	20.6±0.52	24.6±3.15	92.8±9.68	78.3±9.18	98.0±2.45
upperEx (n=8)	20.6±0.74	24.6±2.93	92.9±8.84	83.5±13.08	98.4±0.52
lowerEx (n=8)	20.8±0.46	23.4±2.47	91.5±8.62	90.0±6.80	98.3±0.71

data = mean±SD ; f= fasting condition
no sig. diff. among groups (p≥0.05)

Table 2. Blood glucose (mg/dL) in each group

Group	BG_30'	BG_60'	BG_90'	BG_120'
control (n=8)	131.9±15.49	111.3±12.83[a]	87.0±8.55	90.4±7.35
upperEx (n=8)	120.6±10.00	90.0±12.13[b]	89.8±4.17	86.5±7.11
lowerEx (n=8)	122.9±13.25	92.9±9.73[b]	94.0±8.04	89.8±10.42

data = mean±SD
diff.superscript showed sig.diff between groups (p<0.05)

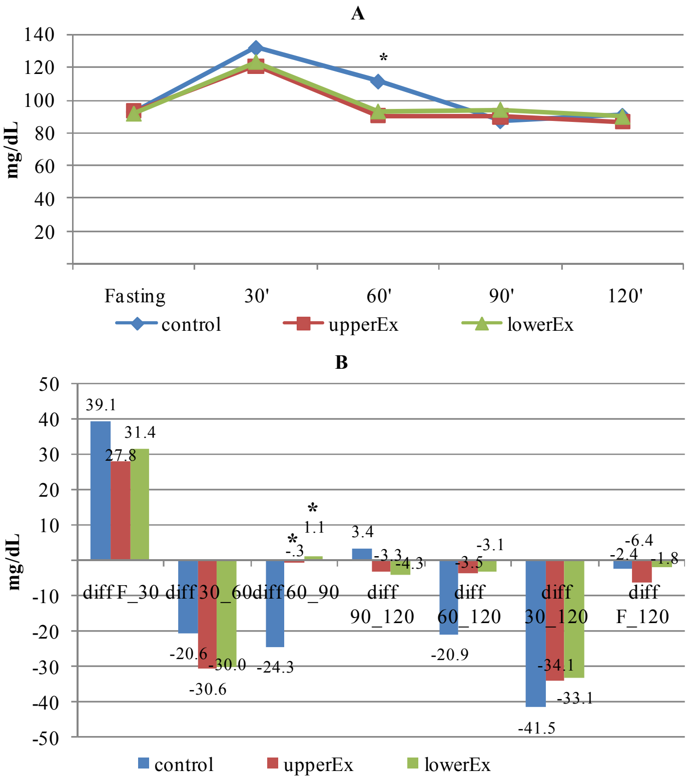

Fig. 1. A: Blood glucose (mg/dL) pattern in the timeline, *sig.diff among groups (p=0.003);
B: Blood glucose difference (mg/dL), *sig.diff with control groups (p<0.05).

Table 3. Heart rate (bpm) in each group

Group	HR_30'	HR_60'	HR_90'	HR_120'
control (n=8)	76.3±11.31	75.4±11.40^{a}	79.5±11.30^{a}	76.0±14.22^{a}
upperEx (n=8)	84.3±10.33	112.1±13.56^{b}	89.0±12.14^{a,b}	86.3±15.99^{a,b}
lowerEx (n=8)	87.9±8.54	132.0±9.43^{c}	94.5±9.67^{b}	94.0±6.44^{b}

data = mean±SD
diff.superscript showed sig.diff between groups (p<0.05)

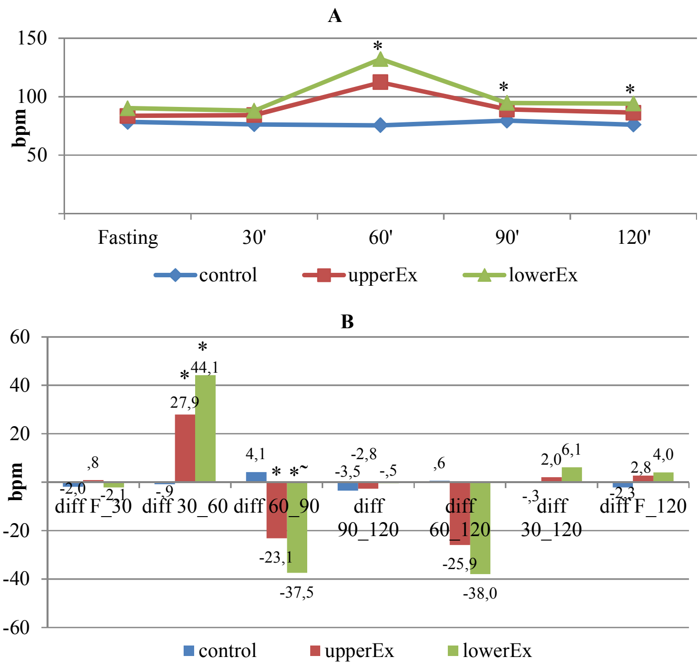

Fig. 2. A: Heart rate (bpm) pattern in the timeline, *sig.diff among groups (p<0.05) ;
B: Heart rate difference (bpm), *sig.diff with control groups (p<0.05), ~ sig.diff with upperEx group (p<0.05).

Table 4. The percentage of saturated pressure of oxygen (%)

Group	SpO_2_F	SpO_2_30	SpO_2_60	SpO_2_90	SpO_2_120
control (n=8)	98.0±2.45	98.9±0.64	98.8±1.03	98.5±0.54	98.3±0.46
upperEx (n=8)	98.4±0.52	98.0±1.77	97.9±1.00	98.5±0.76	98.3±0.46
lowerEx (n=8)	98.3±0.71	98.8±0.89	98.1±0.35	98.3±0.46	98.4±0.52

data = mean±SD
no sig.diff among groups (p≥0.05)

Tabel 5. The significant correlation (Spearman's Rho) between blood glucose and heart rate or percentage of oxygen saturation in each group

control	upperEx			lowerEx		
		coeff.	Sig.		coeff.	Sig.
no sig. correlation	BG_120' & HR_60'	0,857	0,007	BG_60' & HR_60'	0,715	0,046
	BG_120' & SpO_2_120'	-0,756	0,030	BG_90' & HR_60'	0,904	0,002
				BG_90' & SpO_2_120'	-0,732	0,039

Dicussion

Upper and Lower Only Extremities Exergaming on Serial Blood Glucose Levels

The 60' BG or the glucose level measured immediatley after exergaming was significantly lower in the treatment groups. There was also a greater difference in the mean decrease compared to control. The decrease in blood glucose levels in upperEx and lowerEx groups could be caused by an increase usage of blood glucose in skeletal muscles when physical exercise took place. As explained by Richter et al. (1985) and Colberg et al. (2013), based on the type, intensity, and duration, exercise has been found to significantly reduce blood glucose levels. In addition, a greater decrease in blood glucose level in the upperEx and lowerEx groups was also influenced by several other factors, such as the increases of capillary blood flow, causing the distribution of insulin and glucose in muscle cells to occur faster. In addition to, insulin also affects the redistribution of GLUT-4 (glucose transporters-4) from the inner cell to the cell surface so that the facilitated diffusion of glucose into the cell can be done (Herawati, Irwadi, Sari, & Harjanto, 2015).

After 60 minutes, blood glucose levels in the control group decreased drastically which was predicted to contribute to hypoglycemia compared to the treatment groups. This is because after four to eight hours, the circulation of nutrients from exogenous will return to the phase before eating. This was followed by an increase in food circulation endogenously, where 90% of glucose production derived from glycogenolysis and gluconeogenesis in the liver (Paffenbarger et al., 1976). On the other hand, an increase in blood glucose levels due to glycolysis and gluconeogenesis in the liver will increase insulin secretion to maintain a balance of blood glucose levels after physical exercise (Wulandari, 2013).

A slower decrease in glucose levels after 60 to 120 minutes in the treatment groups might happen to healthy individuals. This result is in accordance with a study conducted by Swanwick and Matthews (2018), where there was a temporary increase in blood sugar levels in swimmers which caused an increase in catecholamines and other independent hormones.

Exercising upper only and lower only through exergaming resulted in a similar pattern of serial blood glucose. However, the decrease in the lower only exergaming group was more significant than that in the upper only exergaming group. It might be the effect of the lower exergaming type which requires more energy, such as weight-bearing exercise like running compared to non-weight bearing exercise like swimming (University of Colorado Hospital, 2004; Harvard Health Publishing, 2004).

The Effect of Upper and Lower Only Extremities Exergaming on Heart Rate

Previous studies have suggested that exergaming is equivalent to mild-moderate intensity of physical activity (Kraft, 2011; Ruivo, 2014). Also, it has been known that exercise will stimulate symphatetic nerves and the result is increased heart rate (HR) (Hall & Guyton, 2016). In this study, the HR of lower only extremities is similar to that of a prior study conducted by Kraft, (2011). The HR of individuals doing upper only extremities exergaming is similar to that doing mild exercise (Foss & Keteyian, 1998). The HR of individuals doing upper only extremities exergaming showed a slower increase compared to those doing the lower only extremities exergaming, but it was not significantly different. Thus, upper only extremities exergaming seems to give more benefit to a person who has metabolic diseases such as heart disease.

The recovery of HR between 60 and 90 minutes after exergaming showed insignificant difference between upper and lower groups. The lower exergaming presented a faster decrease of HR. Yet, after 90 and 120 minutes of exergaming, the control and treatment groups had the same pattern.

Heart rate and oxygen saturation had a significant correlation. This result is in line with research conducted by Lain (2013).The increase in heart rate was relatively not extreme. Therefore, blood glucose levels were still within the normal range. Several articles reveal that physical activities or exercises with submaximal intensity will lead to an increase in blood glucose levels and a decrease after ~30 minutes (Adams, 2013;

Goodwin, 2010). It is because in high intensity exercise, adrenalin will be secreted higher to stimulate hepatic glycogenolysis or gluconeogenesis in order to maintain blood glucose levels for important organs especially the brain (Goodwin, 2010).

The Effect of Upper and Lower Only Extremities Exergaming on Oxygen Saturation

Oxygen saturation was found to be insignificantly different among groups. This finding is different from the result of a previous study on patients with severe COPD (chronic obstructive pulmonary disease) (Wardini et al., 2013). The different result could be because the participants in this study were normal teenagers and the method of exercise was different. The exercise in this study was dancing and the intensity was mild to moderate.

According to a research by Lain and Granger (2013), an increased heart rate of more than 180 bpm could lead to oxygen desaturation. The reason lies in the heart rate which increases after exergaming, not exceeding 180 bpm. Thus, there was no oxygen desaturation.

Based on the correlation test, there was a significant negative correlation between blood glucose and oxygen saturation. This aligns with research conducted by Acar et al. (2014) and Wei et al. (2016). This indicates that when there was a decline in oxygen saturation (e.g. during high-intensity physical exercise or hypoxic state), the blood glucose level increases. However, the level of those variables was still within the normal range. Thus, exergaming is relatively safe to do.

Conclusions

The upper and lower only exergaming have an effect on serial blood glucose levels and heart rates. However, they do not affect the oxygen saturation in teenagers. Thus, they may prevent metabolic diseases since teenager phase. We also assume that the upper exergaming is less harmful for a person who has metabolic diseases. Further research could examine this aspect.

Conflicts of interest

The authors declare no conflicts of interest in relation to the research reported in the article.

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