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EFFECT OF HAEMOGLOBIN GENOTYPE ON EXERCISE TOLERANCE AMONG BINGHAM UNIVERSITY STUDENTS

Mahan Josiah Mallo[1,2], Joan Eni Eleojo-Wofa[1], Abiodun Joel Oladejo[3], John Olubanji Ogundiran[1] and Joseph Emberga Toryila[1]
[1]Faculty of Health Sciences, Plateau State University, Bokkos
Nigeria
[2]Department of Human Physiology, Bingham University, Karu,
[3]Department of Geography and Environmental Management, University of Abuja
Corresponding Authors Email: mahanm@plasu.edu.ng, mallomahan@gmail.com Phone: +2348035362454

Abstract

Haemoglobin, the protein responsible for transporting oxygen in the blood, can vary in structure due to genetic factors, such as those associated with sickle cell trait or thalassemia. This variability can influence an individual's ability to tolerate exercise, as different hemoglobin genotypes may impact oxygen delivery to muscles during physical activity. This study was designed to investigate the effect of haemoglobin genotype on exercise tolerance among students of Bingham University, Nigeria. A total of 120 Bingham University students, encompassing both genders and aged between 16-26, were used in the study. Questionnaires were administered to check indices such as their age, sex, height, weight, haemoglobin genotype, exercise habits and health history. The values of some physiological parameters: heart rate, respiratory rate, peak flow expiratory rate, systolic and diastolic blood pressure of the subjects were checked before using the treadmill, immediately after the treadmill and 5 minutes after using the treadmill. The results obtained revealed a statistically significant ($p < 0.05$) increased in all the physiological parameters among all the haemoglobin genotypes (AA, AS and SS) immediately after exercise and 5 minutes after exercise compared to before exercise. There was also a statistically significant ($p < 0.05$) increase in heart rate and respiratory rate immediately after exercise and five minutes after exercise in subjects with haemoglobin genotype AS and SS compared to individuals with AA haemoglobin genotype. The increased heart rate and respiratory rate occur due to significantly impaired oxygen delivery caused by the sickling of red blood cells, which blocks capillaries and reduce blood flow. In conclusion, haemoglobin genetic variations play a significant role in determining individual differences in physical performance, endurance, and response to training.

Keywords: Haemoglobin, genotype, exercise, respiratory rate, heart rate

Introduction

Hemoglobin genotype refers to the genetic makeup that determines the specific type of hemoglobin inherited in an individual's red blood cells (Barrera-Reyes et al., 2019). They include mutations like hemoglobin S, C, D, and E, leading to abnormal hemoglobin genotypes such as AS, AC, SC, and SS, common among Nigerians and associated with significant morbidity and mortality (Ojewumi et al., 2019). Hemoglobin genotypes play a crucial role in conditions like sickle cell disease, where the genotype determines the presence of abnormal hemoglobin (Aleluia et al., 2017).

The prevalence of hemoglobin genotypes in Nigeria varies, with the most common genotype being Hb AA (Adeyemi et al., 2016). The prevalence of the Hb AA genotype in Nigeria is estimated to be around 60-70% of the population (Abdulrahaman et al., 2013). The second most common genotype is Hb AS. About 20-30% of the Nigerian population is estimated to carry the sickle cell trait (Hb AS). This genotype is a carrier state for sickle cell disease, meaning an individual has one normal hemoglobin gene and one sickle cell gene (Xu & Thein, 2019). The high prevalence of the Hb AS genotype in Nigeria is a significant public health concern, as individuals with this genotype are at risk of passing sickle cell disease on to their offspring (Umoh et al., 2010). In Nigeria, the prevalence of Hb SS, which refers to sickle cell disease (SCD) or homozygous sickle cell anemia, is one of the highest in the world (Kingsley et al., 2019). It is estimated that around 2-3% of newborns in Nigeria are born with sickle cell disease (Hb SS). This means that approximately 1 in every 40 to 50 births in Nigeria will have sickle cell anemia Nnodu et al., 2021). Sickle cell disease remains the most common life-threatening genetic disorder worldwide. Globally about 312,000 children are born each year with sickle cell disease (SCD), half of which are from Nigeria[8]. SCD is a severe and lifelong genetic disorder that affects the structure and function of hemoglobin. People with SCD experience episodes of severe pain, known as sickle cell crises, which can lead to organ damage, stroke, and other complications (Pecker & Lanzkron, 2021). The disease can also cause significant morbidity and mortality, particularly in resource-limited settings where access to medical care and treatment is limited (Kato et al., 2018). Other less common genotypes in Nigeria include HbAC, HbSC, HbCC, and others, which are found in much smaller proportions of the population (Erhobor et al., 2010).

The distribution of hemoglobin genotypes in Nigeria is important for health planning, genetic counseling, informed reproductive health choices, and secondary prevention of hemoglobinopathies (Elsayed et al., 2022).

Materials And Methodology

Materials

The following is the list of materials that were used in conducting this study:

1. Treadmill
2. Stethoscope
3. Sphygmomanometer
4. Peak Flow Meter
5. Laboratory Consumables (gloves, cotton wool, and methylated spirit)
6. Questionnaires
7. Baseline Measurement Tools (e.g., Scales)
8. Data Recording Tools

Ethical Approval

Ethical approval was obtained from Bingham University Research Ethical Committee.

Methodology

For this research, a treadmill was used to assess exercise tolerance and investigate the effect of hemoglobin genotype on it. The detailed methodology employed in this study is as follows:

1. A diverse sample of Bingham University students was recruited, ensuring representation across different hemoglobin genotypes (AA, AS, SS).

2. Questionnaires were given to all participants to obtain their informed consent after the study's purpose and procedures had been explained.
3. Pre-screening assessments were conducted to ensure participants were healthy and eligible for exercise testing. Individuals with cardiovascular or respiratory conditions and those on medications that might affect exercise tolerance were excluded.
4. Participants' baseline characteristics including age, gender, weight, height, and resting heart rate were collected.
5. The respiratory rates of participants were measured manually by observing the rise and fall of their chest and counting the number of breaths per minute using a stopwatch.
6. During the testing, the treadmill protocol for all participants, including warm-up, exercise intensity progression, and cool-down, was standardized. Additionally, the heart rate, respiratory rate, blood pressure, and perceived exertion of participants throughout the treadmill test were monitored, and the test was terminated once participants reached their maximum exertion level or experienced any adverse symptoms.
7. The heart rate, respiratory rate, blood pressure, and peak expiratory flow rate of participants before running on a treadmill and afterward were recorded.
8. The duration of exercise completed by each participant before reaching exhaustion was recorded. Any symptoms experienced during the test, such as shortness of breath, dizziness, or chest pain, were also recorded.
9. The exercise tolerance measures (e.g., respiratory rate, heart rate, blood pressure) across different hemoglobin genotypes were compared.
10. After conducting the test, the findings were presented clearly and concisely, discussing implications for understanding the relationship between hemoglobin genotype and exercise tolerance. Additionally, the limitations of the study and potential directions for future research in this area were discussed.

Data Analysis

Descriptive statistics for categorical variables were presented in frequencies and percentages, while those of continuous variables were presented in mean ± SD (mean and standard deviation). A repeated measurement analysis of variance (ANOVA) was first applied to determine whether timing the exercise tolerance of the various physiological parameters exhibited significant differences. Statistical analyses were done using IBM SPSS version 26 (IBM SPSS Inc., Chicago, IL, USA), and $P < 0.05$ was considered statistically significant.

Results

Participants Characteristics at Baseline

Table 1: shows the result of the participant's characteristics at baseline with n=120. From the result, the male participants were 32 corresponding to 27.5 % while the female participants were 88 with a corresponding percentage value of 72.5 %. For the genotype, 69.2 % were AA, 23.3 % were AS and 7.5 % were SS. Of the total number of participants examined, 66.7 % practiced regular exercise whereas, 33.3 % did not indulge in any form of exercise. On the Anthropometrics, the mean value recorded for all the participants was 1.68 ± 0.10 m for height, 68.23 ± 14.76 kg for weight and the mean body mass index (BMI) for the participants was 22.93 ± 5.62 kg/m^2.

Table 1: Participants characteristics at baseline (n = 120).

Participants characteristics	Frequency	Percentage (%)
	Sex	
Male	32	27.5
Female	88	72.5
	Genotype	
AA	83	69.2
AS	28	23.3
SS	9	7.5
	Regular Exercise	
Yes	80	66.7
No	40	33.3
	Anthropometrics Mean ± SD	
Height (m)	1.68 ± 0.10	
Weight (kg)	68.23 ± 14.76	
BMI (kgm^{-2})	22.93 ± 5.62	

Physiological Parameters Based on Exercise Tolerance Levels at Different Times

The physiological parameters of the participants based on exercise tolerance levels before exercise (T1), immediately after exercise (T2), and five minutes later (T3) are presented in Table 2 below. From the result, an increase was observed in the parameters moving from T1 to T2 but a decrease was observed after 5 minutes of exercise. A statistical difference was observed for all the parameters both before and after exercise at $p<0.05$.

Table 2: Physiological parameters based on exercise tolerance levels at different times.

	TIME		
Physiological parameters	T1	T2	T3
Heart rate (bpm)	72.16 ± 8.47^{a}	92.59 ± 15.94^{b}	82.59 ± 10.48^{c}
SBP (mmHg)	113.38 ± 16.51^{a}	139.57 ± 19.41^{b}	126.49 ± 15.51^{c}
DBP (mmHg)	76.15 ± 9.06^{a}	83.53 ± 13.05^{b}	79.88 ± 9.02^{c}
PEFR (L/min)	290.71 ± 89.70^{a}	322.43 ± 85.44^{b}	306.58 ± 80.16^{ab}
RR (bpm)	17.73 ± 0.67^{a}	29.60 ± 2.05^{b}	23.88 ± 1.12^{c}

T1: Before exercise, T2: immediately after exercise, T3: 5-Min later. HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, PEFR: Peak expiratory flow rate, RR: Respiratory rate. Values are

expressed as Mean ± SD. Values with the same superscript are not statistically significant while those with different superscripts are statistically significant at $p<0.05$

Physiological Parameters and Genotypes at Different Times for Male Subjects

The result for the physiological parameters and genotypes at different times for male subjects is presented in Table 3. The result showed that there was no statistical difference between the genotype and the parameters before exercise (T1) but immediately after exercise (T2), a statistical difference was observed in the HR and RR for the different genotypes whereas for SBP, DBP, and PEFR, no statistical difference was observed. A similar trend in T2 was also observed for T3 (5-Min later).

Table 3: Physiological parameters and genotypes at different times for male subjects.

Time	Genotype	n	HR (bpm)	SBP (mmHg)	DBP (mmHg)	PEFR (L/min)	RR (bpm)
T1	AA	23	71.61 ± 7.86^{a}	112.17 ± 12.78^{a}	74.35 ± 5.90^{a}	349.13 ± 111.31^{a}	17.96 ± 0.88^{a}
	AS	6	72.00 ± 7.18^{a}	108.33 ± 7.53^{a}	73.67 ± 5.72^{a}	311.67 ± 114.96^{a}	17.50 ± 0.55^{a}
	SS	3	80.33 ± 9.50^{a}	116.67 ± 5.77^{a}	76.67 ± 5.77^{a}	416.67 ± 28.87^{a}	17.33 ± 1.15^{a}
T2	AA	23	88.65 ± 12.77^{a}	141.30 ± 21.38^{a}	80.43 ± 13.31^{a}	368.70 ± 95.17^{a}	30.00 ± 1.24^{a}
	AS	6	109.00 ± 16.91^{b}	141.67 ± 9.83^{a}	88.33 ± 7.53^{a}	370.00 ± 121.66^{a}	27.67 ± 1.86^{b}
	SS	3	116.67 ± 15.28^{b}	143.33 ± 5.77^{a}	85.00 ± 5.00^{a}	350.00 ± 0.00^{a}	30.00 ± 2.00^{a}
T3	AA	23	80.35 ± 9.19^{a}	126.74 ± 14.03^{a}	77.39 ± 7.37^{a}	358.91 ± 88.42^{a}	24.22 ± 0.80^{a}
	AS	6	90.67 ± 11.81^{ab}	125.00 ± 7.75^{a}	81.00 ± 6.00^{a}	340.83 ± 117.11^{a}	22.67 ± 1.03^{b}
	SS	3	98.67 ± 12.06^{b}	130.00 ± 5.00^{a}	81.00 ± 5.29^{a}	383.33 ± 14.43^{a}	23.67 ± 0.58^{ab}

T1: Before exercise, T2: immediately after exercise, T3: 5-Min later. HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, PEFR: Peak expiratory flow rate, RR: Respiratory rate. Values are expressed as Mean ± SD. Values with the same superscript are not statistically significant while those with different superscripts are statistically significant at $p<0.05$

4 Physiological Parameters and Genotypes at Different Times for Female Subjects

The result for physiological parameters and genotypes at different times for female subjects is presented in Table 4. Similar to those observed for the male participants, no statistical difference was observed for in the parameters against the genotypes at T1 except for DBP and PEFR. At T2, a statistical difference was also observed for HR and RR whereas at T3, no difference was observed for all the parameters except for RR where a difference was observed in the respiratory rate of the SS genotypes.

Table 4: Physiological parameters and genotypes at different times for female subjects.

Time	Genotype	n	HR (bpm)	SBP (mmHg)	DBP (mmHg)	PEFR (L/min)	RR (bpm)
T1	AA	60	71.12 ± 9.23^{a}	113.67 ± 16.54^{a}	77.50 ± 10.73^{a}	265.28 ± 67.85^{a}	17.65 ± 0.55^{a}
	AS	22	73.41 ± 7.10^{a}	116.55 ± 23.37^{a}	77.00 ± 8.05^{a}	266.73 ± 80.03^{a}	17.73 ± 0.70^{a}
	SS	6	76.17 ± 7.19^{a}	106.83 ± 6.01^{a}	68.67 ± 3.83^{b}	325.00 ± 68.92^{b}	18.00 ± 0.63^{a}
T2	AA	60	92.18 ± 15.73^{a}	140.15 ± 21.49^{a}	84.57 ± 13.84^{a}	310.03 ± 74.10^{a}	29.67 ± 1.11^{a}
	AS	22	87.82 ± 15.42^{ab}	138.18 ± 16.51^{a}	82.50 ± 13.78^{a}	$293.18 \pm 84.03_{a}$	28.41 ± 2.11^{a}
	SS	6	100.83 ± 10.21^{b}	128.33 ± 7.53^{a}	83.33 ± 7.53^{a}	315.00 ± 77.14^{a}	33.50 ± 5.01^{b}
T3	AA	60	81.87 ± 10.44^{a}	126.93 ± 17.03^{a}	81.05 ± 10.60^{a}	287.67 ± 65.14^{a}	23.87 ± 0.75^{a}
	AS	22	80.86 ± 9.39^{a}	127.36 ± 17.04^{a}	79.82 ± 7.44^{a}	279.95 ± 76.75^{a}	23.41 ± 1.18^{a}
	SS	6	88.67 ± 8.31^{a}	117.67 ± 5.92^{a}	76.17 ± 5.42^{a}	320.00 ± 68.92^{a}	25.83 ± 2.32^{b}

T1: Before exercise, T2: immediately after exercise, T3: 5-Min later. HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, PEFR: Peak expiratory flow rate, RR: Respiratory rate. Values are expressed as Mean ± SD. Values with the same superscript are not statistically significant while those with different superscripts are statistically significant at $p<0.05$

Physiological Parameters and Genotypes at Different Times for All Subjects

Presented in Table 4.5 is the result of the physiological parameters and genotypes at different times for all subjects. From the result, it was observed that there was no statistical difference for SBP, DBP, and RR at T1, while a difference was seen in HR and PEFR for the AA and SS participants. At T2, a statistical difference was observed for SBP of the SS genotype participants in addition, the RR also recorded a difference in all the genotypes. Finally, at T3, a difference was also observed in the heart rate (HR) of the SS genotype subjects the respiratory rate for all the genotypes was also significant at $p<0.05$.

Table 5: Physiological parameters and genotypes at different times for all subjects

Time	Genotype	n	HR (bpm)	SBP (mmHg)	DBP (mmHg)	PEFR (L/min)	RR (bpm)
T1	AA	83	71.25 ± 8.82[a]	113.25 ±15.52[a]	76.63 ±9.71[a]	288.52 ±89.79[a]	17.73 ±0.66[a]
	AS	28	73.11 ±7.01[ab]	114.79 ±21.15[a]	76.29 ±7.64[a]	276.36 ±88.22[a]	17.68 ±0.67[a]
	SS	9	77.56 ±7.70[b]	110.11 ±7.42[a]	71.33 ±5.79[a]	355.56 ±72.65[b]	17.78 ±0.83[a]
T2	AA	83	91.20 ±14.98[a]	140.47 ±21.34[a]	83.42 ±13.74[a]	326.29 ±84.13[a]	29.76 ±1.15[a]
	AS	28	92.36 ±17.78[a]	138.93 ±15.24[a]	83.75 ±12.81[a]	309.64 ±96.24[a]	28.25 ±2.05[b]
	SS	9	106.11 ±13.64[a]	133.33 ±10.00[b]	83.89 ±6.51[a]	326.67 ±63.44[a]	32.33 ±4.44[c]
T3	AA	83	81.45 ±10.08[a]	126.86 ±16.17[a]	80.02 ±9.89[a]	307.40± 78.62[a]	23.96 ±0.77[a]
	AS	28	82.96 ±10.55[a]	126.86 ±15.43[a]	80.02 ±7.09[a]	293.00 ±.14[a]	23.25 ±1.17[b]
	SS	9	92.00 ±10.22[b]	121.72 ±8.13[a]	77.61 ±5.46[a]	341.11 ±63.43[a]	25.11 ±1.12[c]

T1: Before exercise, T2: immediately after exercise, T3: 5-Min later. HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, PEFR: Peak expiratory flow rate, RR: Respiratory rate. Values are expressed as Mean ± SD. Values with the same superscript are not statistically significant while those with different superscripts are statistically significant at $p<0.05$

Discussion

The results from the study revealed a statistically significant ($P < 0.05$) increase in all physiological parameters (heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, and peak expiratory flow rate) in all the haemoglobin genotypes (AA, As, and SS) immediately after exercise and five minutes after exercise compared to before exercise. Also, from the results, the male participants with genotypes AS and SS experienced a statistically significant ($p < 0.05$) increase in heart rate and respiratory rate immediately after exercise and five minutes after exercise, compared to before exercise. However, there were no changes observed in the other physiological parameters (systolic blood pressure, diastolic blood pressure, and peak expiratory flow rate). However, in the female subjects, there was a statistically significant ($p < 0.05$) increased in respiratory rate five minutes after exercise in the SS genotype compared to the AA and AS subjects, but there were no changes in the other physiological parameters (heart rate, systolic blood pressure, diastolic blood pressure, and peak expiratory flow rate).

The significant ($p < 0.05$) increase in HR and RR immediately after exercise occurs due to the higher oxygen demands of muscles during exercise. In the SS genotype, a more pronounced increase in HR and RR occurs due to significantly impaired oxygen delivery caused by the sickling of red blood cells, which blocks capillaries and reduces blood flow (Coote, 2010). Also, exercise stimulates the sympathetic nervous system, causing an increase in HR and RR across all genotypes. However, the extent of this increase can vary based on the

efficiency of oxygen delivery and the individual's overall cardiovascular health (Verweij et al., 2018). The cardiovascular system increases HR to pump more blood (and thus more oxygen) to the muscles. The pulmonary system increases RR to enhance oxygen uptake and carbon dioxide removal. Typically, HR and RR start to decrease as the parasympathetic nervous system activates to promote recovery. The recovery time of genotype AS may be slower compared to AA, with HR and RR remaining elevated for a longer period due to less efficient oxygen delivery (Nair et al., 2022). While for SS, the recovery rate is usually the slowest. HR and RR remain elevated for a more extended period as the body struggles to return to baseline due to poor oxygenation and potential microvascular occlusions (Williams, 2018).

In general, students with genotype AA typically showed the highest levels of exercise tolerance. Those with genotype AS exhibited normal exercise tolerance but could face complications under extreme conditions like high-intensity exercise, dehydration, or high altitudes. Students with genotype SS had significantly reduced exercise tolerance due to decreased oxygen-carrying capacity, muscle fatigue and pain, poor blood flow, and chronic anemia.

The findings of this study is not in line with the research done by Badawy et al (2018) who reported that blood genotype is not associated with exercise tolerance capacity.

Similarly, the findings from this study aligned with the study of Bouchard et al (2011) on the impact of hemoglobin genotype on exercise tolerance which stated that genotype influences several exercise phenotypes in recreational marathoners.

Conclusion

In conclusion, different haemoglobin genotypes significantly influence exercise tolerance levels in both male and female. The haemoglobin genetic variations play a significant role in determining individual differences in physical performance, endurance, and response to training. These genetic factors contribute to the variability seen in exercise tolerance, highlighting the importance of personalized approaches to fitness and health based on genetic makeup.

Conflict of Interest

The authors declare no conflict of interest on this research work.

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