Assessment of cardiorespiratory fitness in medical students using the Queen's College Step Test: A gender-based analysis of VO_{2max}

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ABSTRACT

Introduction: VO2max, a measure of the maximum oxygen uptake during physical exertion, is a critical indicator of cardiovascular fitness. Evaluating VO_{2max} in young adults helps in understanding their fitness levels and guiding improvements. This study aimed to assess normal VO2max levels and investigate the relationships between oxygen saturation (SpO_2) and VO_{2max}, as well as between blood pressure and VO_{2max}, in both male and female participants. **Methods:** A total of 93 students (45 males, 48 females) aged 18 to 25 years from Gandaki Medical College, Pokhara, were selected through simple random sampling. VO2max was estimated using the Queen's College Step Test (QCT), a widely accepted indirect method to assess cardiorespiratory fitness. QCT provides a convenient way to evaluate maximum oxygen uptake in a non-laboratory setting. **Results:** The mean VO2max for male participants was 62.00±8.77 ml/kg/min, while for females, it was 41.79±3.18 ml/kg/min. Males exhibited significantly higher VO_{2max} values compared to females ($p<0.001$). Both diastolic blood pressure ($p = 0.013$) and SpO_2 ($p < 0.001$) were found to have a significant influence on VO_{2max} in female but not changed in the male. **Conclusions:** This study confirms that gender-related differences in cardiovascular fitness exist, with males generally showing higher endurance levels compared to females. The lower VO_{2max} values observed in females were primarily associated with variations in SpO_2 and diastolic blood pressure. These findings highlight the importance of considering physiological variables such as oxygen saturation and blood pressure in the assessment of female cardiorespiratory fitness.

Keywords: Cardio respiratory fitness, diastolic blood pressure, SpO_2, Step test, $VO_{2max.}$

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Submitted: September 18, 2024
Accepted: November 27, 2024

To cite: Prajapati R, Amatya N, Shrestha R, Magar RR, Amatya M. Assessment of cardiorespiratory fitness in medical students using the Queen's College Step Test: A gender-based analysis of VO2max. JGMC Nepal. 2024;17(2):105-10.
DOI: 10.3126/jgmc-n.v17i2.69901

INTRODUCTION

Physical fitness is regarded as a crucial health marker and a predictor of both morbidity and mortality for cardiovascular disease and overall health.[1] Cardio-respiratory fitness reflects the capability of the circulatory system to deliver oxygen to active muscles during sustained physical activity. The maximal oxygen consumption, known as VO_{2max}, achieved during a graded maximal exercise test to voluntary exhaustion, is recognized by the World Health Organization as the premier measure of cardio-respiratory fitness.[2] VO_{2max} is a critical factor for endurance exercise performance because it sets the upper limit for aerobic metabolism.[3,4] The primary limitation of VO_{2max} is the rate of oxygen delivery to the working muscle,[5] many physiological parameters that influence oxygen delivery during exercise have been described previously.[6]

VO_{2max} can be estimated through both maximal and submaximal tests, using direct or indirect methods. The most frequently used tests for estimating VO_{2max} include walking or running tests, followed by cycling and step tests.[7] Among these, the step test is a widely recognized practical field test for evaluating individual aerobic

fitness, making VO_{2max} a key marker of physical fitness and the most reliable indicator of aerobic fitness.[8] One parameter that influences VO_{2max} is the total mass of hemoglobin in circulation (tHb). tHb influences VO_{2max} both via its relationship with hemoglobin concentration ([Hb]) and arterial oxygen content (O_2),[9] and via its relationship with total blood volume, venous return and ventricular filling, and maximal cardiac output.[10] However, tHb is not the only factor that influence O_2; arterial oxygen saturation (SpO_2) also influences O_2. During high-intensity exercise, SpO_2 can drop significantly in a variety of athletes; this condition is known as exercise-induced arterial desaturation (EIAD).[11] Although tHb and EIAD both influence oxygen delivery during exercise, to date there have been no studies looking at how these factors interact to influence VO_{2max}.

Medical students, who are future physicians, need to maintain both physical fitness and mental alertness. Despite this, they often engage in limited physical activity and experience considerable stress due to demanding academic responsibilities. It is crucial for these students to assess and analyze their physical fitness to enhance their overall well-being and performance. Adequate physical fitness is vital for improved productivity, health, and general quality of life. This study aimed to assess normal VO_{2max} levels and investigate the relationships between oxygen saturation (SpO_2) and VO_{2max}, as well as between blood pressure and VO_{2max}, in both male and female participants. Prior research suggests that females might be more susceptible to EIAD compared to males due to anatomical differences.[12] However, direct comparisons of SpO_2 between males and females are limited in our region. To bridge this gap, this study aimed to examine the correlation between SpO_2 and VO_2max in both male and female participants.

METHODS

This is a cross sectional study carried out among the healthy 45 male and 48 female subjects between age group of 18 to 25 years. The study was conducted in the Gandaki Medical College Teaching Hospital and Research Center, Pokhara, Nepal over a period from June to August 2024. Ethical clearance was obtained from the Institutional ethical review committee board, Gandaki Medical College (Ref. No. 93/080/081-F). All the recordings were taken in the skill lab in the Department of Physiology under laboratory condition (26±2^oC). The subjects were given a detailed explanation of the study and were asked to sign a written consent form. Before the test the subjects were instructed not to indulge in any activities. Subjects were also instructed not to have heavy meals/tea/coffee at least two hours before test. The anthropometric data which included age, height, weight was noted, and Body Mass Index (BMI) was calculated. Before commencement of test the subjects were asked to rest, then all basal parameters like pulse rate, blood pressure and SpO_2 were measured. Pulse rate and SpO_2 were measured by Color Pulse Oximeter, model:CMS60C, PRC. The relevant alcoholic history and smoking habits were elicited from each subject to make sure that the subjects included in the study satisfied the criteria of normal and healthy individual. The subjects were apparently fit, receiving no medication at the time of the study. The sample size was calculated based on previous study[13] using the formula $n=2(Z_\alpha+Z_{1-\beta})^2\sigma^2/\Delta^2$. Standard deviation $\sigma = 8.96$, estimated effect size $\Delta=7.81$, $Z_\alpha=1.96$ (at 5% level of significance), $Z_{1-\beta}= 0.8416$ (at power of 80%). The desired sample size was 30; however, the final sample consisted of 45 male participants and 48 female participants.

VO_{2max} was estimated indirectly by following the protocol of Queen's College Step Test [QCT] method.[14] The step test was performed using a tool of 16.25 inches height. Stepping was done for a total duration of 3 minutes at the rate of 24 steps up per minute for males and 22 steps up per minute for females which was set by a metronome. After completion of exercise, the pulse rate was measured by using pulse oximeter and following equation was used to predict VO_{2max}. SpO_2 and blood pressure were simultaneously measured alongside pulse rate to assess these parameters at the VO_{2max} level.

For males:
VO_{2max} = 111.33 – [0.42 × pulse rate beats/min] [ml/kg/min]
For females:
VO_{2max} = 65.81–[0.1847×pulse rate beats/min] [ml/kg/min]

The SpO_2 and blood pressure were measured immediately after exercise

The data was collected, compiled and analyzed using statistical package for social sciences (SPSS) software version 17.0. Analysis was done using descriptive statistics like mean and standard deviation, and inferential statistics like student's t-test and Pearson correlation analysis. The p-value < 0.05 was considered significant.

RESULTS

The normal data between two groups

A total of 93 subjects were included in the study (45 males and 48 females), all of whom had similar age, height, weight, and BMI. There was no statistically significant difference in these baseline characteristics between the

two groups. The general physical and anthropometric data for both groups are presented in Table 1. The lack of significant variation between the male and female groups in these parameters ensures comparability and eliminates potential confounding effects in the analysis of VO_{2max} and other physiological measures.

Table 1: The physical and anthropometric data of both groups and their correlations.

Parameters	Male (n= 45) Mean±SD	Female (n=48) Mean±SD	Pearson correlation	p-value
Age (years)	20.02±0.94	19.02±0.88	0.03	0.87
Weight (kg)	65.66±11.20	51.43±7.98	0.03	0.87
Height (m)	1.67± 0.07	1.54±0.06	0.27	0.07
BMI (kg/m^2)	23.32±3.81	21.43±3.25	-0.11	0.47
Pulse rate at rest (bpm)	78.97±10.54	83.04±9.06	0.03	0.86
Pulse rate at VO_{2max} (bpm)	117.64±20.89	130±17.22	0.03	0.84
SpO_2 at rest (%)	97.577±0.81	97.693±0.56	0.08	0.59
SpO_2 at $VO_{2max.}$ (%)	96.95±1.80	95.12±2.25	0.29	0.06
SBP at rest (mm Hg)	122.62±13.52	107.77±9.10	0.04	0.79
SBP at VO_{2max} (mm Hg)	141.15±14.20	124.77±11.58	<0.05	0.99
DBP at rest (mm Hg)	73.6±7.9	73.95±6.04	0.13	0.40
DBP at VO_{2max} (mm Hg)	69.46±7.63	64.41±6.41	0.25	0.10
Pulse pressure at rest (mm Hg)	49.02±14.52	33.81±10.28	-0.12	0.45
Pulse pressure at VO_{2max} (mm Hg)	71.68±15.48	60.35±13.75	-0.03	0.83

VO_{2max} between two groups

Our analysis revealed that the mean VO_{2max} for male participants was 62.00 ± 8.77 ml/kg/min, while for female participants, it was 41.79 ± 3.18 ml/kg/min. This demonstrates a significantly higher aerobic capacity in males compared to females. (Figure 1)

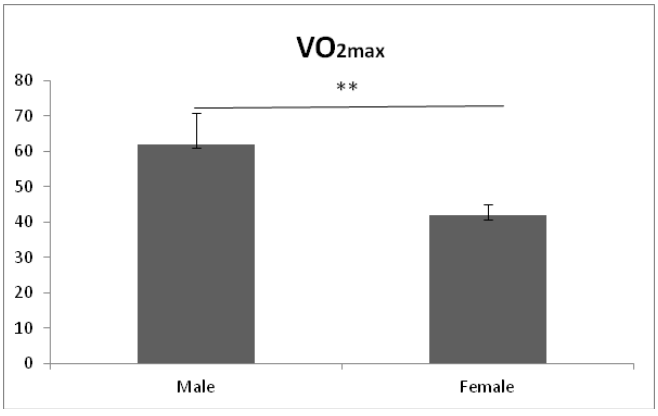


Figure 1: VO_{2max} between male and female. **Correlation is significant at the 0.01 level

Distribution of subjects based on standard VO_{2max} classification

Upon comparing the VO_{2max} values of our participants with the standard VO_{2max} classification, it was observed that the majority of male students fell into the 'excellent' category, indicating a high level of cardiovascular fitness. In contrast, the majority of female students were classified in the 'good' category, reflecting slightly lower, but still above-average, fitness levels. Importantly, there were no participants from either the male or female groups who fell into the 'poor' or 'fair' categories, indicating that all subjects demonstrated at least a moderate level of cardiovascular fitness (Table 2).

Table 2: Distribution of data based on VO_{2max} classification.[13]

Male		Female	
VO_{2max} category	n(%)	VO_{2max} category	n(%)
Poor (≤24.9)	0(0%)	Poor (≤23.9)	0(0)
Fair (25-33.9)	0(0%)	Fair (24-30.9)	0 (0)
Average (34-43.9)	1(2.22%)	Average (31-38.9)	10(20.83)
Good (44-52.9)	7(15.55%)	Good (39-48.9)	39(81.25)
Excellent (≥53)	37(82.22)	Excellent (≥49)	0(0)
Total	45(100)	Total	48(100)

Relationship of Diastolic Blood Pressure with VO_{2max}

In our study, we initially observed no difference in resting diastolic blood pressure (DBP) between males and females (p=0.98). However, during maximal exercise (VO_{2max}), we detected a significant reduction in DBP in females (p=0.398) compared to males (Figure 2). To investigate this further, we analyzed the relationship between DBP and VO_{2max} in both sexes. In males, no significant correlation was found (p=0.928, r=-0.014), indicating that DBP does not appear to be influenced by VO_{2max}. In contrast, a significant negative correlation was observed in females (p<0.001, r=0.356*), suggesting that as VO_{2max} increases, DBP decreases during maximal exercise in females.

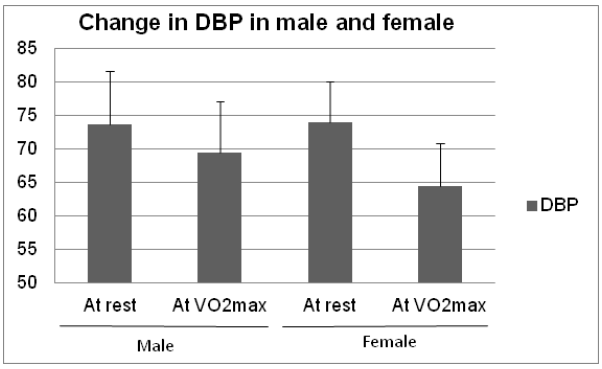
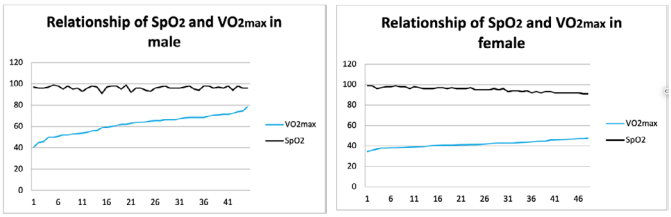


Figure 2: Relationship of diastolic blood pressure (DBP) with VO_{2max}

The relationship of SpO_2 and VO_{2max}

As with diastolic blood pressure (DBP), the SpO_2 also decreases at VO_{2max} in females compared to males. To investigate this further, we analyzed the relationship

between SpO_2 and VO_{2max} in both groups. Our analysis revealed no significant correlation between SpO_2 and VO_{2max} in males (p=0.817, r=-0.035). However, a significant correlation was observed in females (p<0.001, r=-0.930**). There is a notable decrease in SpO_2 with increasing VO_{2max} in females, whereas no such change in SpO_2 is observed with increasing VO_{2max} in males (Figure 3).



A. B.

Figure 3: Relationship of SpO_2 with VO_{2max}. There is a notable decrease in SpO_2 with increasing VO_{2max} in females (B), whereas no such change in SpO_2 is observed with increasing VO_{2max} in males (A)

DISCUSSION

The main outcomes of the present study revealed a significantly higher mean VO_{2max} for males compared to females (p<0.001), consistent with findings from other studies.[15,16] This observed difference in VO_{2max} between genders can be attributed to several physiological factors. Central factors such as pulmonary ventilation, diffusion across the pulmonary capillary membrane, cardiac output, and hemoglobin mass, along with peripheral factors like skeletal muscle blood flow and the diffusion of oxygen from the microcirculation into the muscle, likely contribute to this disparity.[17] Females, generally having smaller hearts, lungs, and lower hemoglobin mass compared to males, may have a reduced capacity to deliver oxygen to working muscles, which could limit their VO_{2max}.

Our results indicated that 82.22% of males were classified as being in excellent health based on VO_{2max}, while no females fell into this category. Conversely, 81.25% of females were categorized as being in good health. This distribution underscores a gender-related difference in aerobic capacity, with males generally exhibiting higher VO_{2max} compared to females, although both groups demonstrated overall good performance.

Furthermore, the study observed a significant decrease in SpO_2 at VO_{2max} in females, which was negatively correlated with VO_{2max}, whereas no significant change in SpO_2 was noted in males. The negative correlation between SpO_2 and VO_{2max} in females suggests that greater oxygen utilization occurs during exercise in females compared to males. The reduction in DBP at VO_{2max} in females likely reflects the intensity of exercise and the associated physiological responses, including heat generation. These findings indicate that differences in $SpO_2$and DBP during maximal exercise may contribute to variations in endurance between males and females. The decrease in diastolic blood pressure observed in females supports this hypothesis, though further research is needed to fully elucidate the relationship between SpO_2 and VO_{2max}.

To our knowledge, this is the first study in our region to examine gender differences in SpO_2 and VO_{2max}. Our results suggest a complex interplay of physiological, anatomical, and environmental factors influencing these variables in females compared to males. One strength of this study was its ability to link higher VO_{2max} observed in males to SpO_2 levels. However, a limitation is the lack of direct measurements of arterial oxygen saturation or oxygen content. While pulse oximetry is a reliable method for measuring SpO_2 during exercise,[18] direct assessments of arterial blood gases, pH, and temperature could provide additional insights. Moreover, cross-sectional data limits the ability to establish causal relationships. Future research should consider factors such as maximal cardiac output and other variables that may influence VO_{2max}.

In our analysis, we found that both diastolic blood pressure (DBP) and oxygen saturation have a significant impact on VO_{2max} in females. Specifically, these variables were identified as key physiological factors influencing maximal oxygen uptake capacity during exercise. The significant effect of DBP suggests that vascular resistance and blood pressure regulation play a critical role in determining exercise capacity in females, potentially due to differences in cardiovascular adaptations compared to males. Similarly, SpO_2, which reflects the efficiency of oxygen transport and utilization, significantly contributes to VO_{2max} in females. This indicates that oxygen saturation is crucial for optimizing aerobic performance, particularly at higher exercise intensities. Together, these findings suggest that the cardiovascular and respiratory systems interact uniquely in females, influencing their VO_{2max} and overall aerobic fitness. Further research is needed to explore the underlying mechanisms of this sex-specific relationship.

CONCLUSIONS

The present study demonstrated a significantly higher mean VO_{2max} in males compared to females, highlighting inherent gender-related differences in aerobic capacity. The findings suggest that in females, SpO_2 and DBP play a critical role in influencing VO_{2max}, likely due to differences in

oxygen utilization efficiency and cardiovascular adaptation during maximal exercise. Further research is required to explore additional factors, such as maximal cardiac output and arterial oxygen content, to gain a deeper understanding of the physiological determinants of aerobic fitness in males and females.

ACKNOWLEDGEMENT

We are grateful to Mrs. Shraddha Hamal, Assistant Professor, Department of Community Medicine, Gandaki Medical College Teaching Hospital Research Center, for statistical analysis.

CONFLICTS OF INTEREST: None declared

SOURCE OF FUNDING: None

AUTHORS' CONTRIBUTION

RP did concept and design of research literature search data collection, analysis and interpretation, manuscript preparation and editing. NA did literature search data collection, analysis and interpretation, and manuscript editing. RRM did data collection, and manuscript editing. RS did manuscript editing and MA did data interpretation and manuscript editing. All the authors have read and approved the final draft.

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