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Acute effects of blood flow restriction on muscle performance and fatigability using Mosso's Ergography in young adults

Kalyan Gautam[1], Gita Khakurel[2], Prabin Kumar Karki[3]

[1]Lecturer, [2]Associate Professor, [3]Assistant Professor, Department of Physiology, Kathmandu Medical College and Teaching Hospital, Nepal

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Abstract

Introduction: Upon contraction, skeletal muscles produce force and power. When contractions are sustained, relative reduction in force and power is observed, a phenomenon termed muscle fatigue. This study aimed to evaluate muscle function and fatigability among young adults along with blood flow restriction using Mosso's ergography.

Method: A prospective repeated-measures study was carried out between 13 Apr and 05 Oct 2023 on healthy students of first-year undergraduates at Kathmandu Medical College. Ethical approval was obtained. Census sampling was used. Participants pulled 2 kg load under no occlusion, venous occlusion and arterial occlusion. Repeated measures were taken for work done (joules) and fatigue onset time (seconds) using Mosso's Ergograph. Statistical analysis was conducted using R Studio (version 4.2). Regression analysis was performed for correlations of muscle function with age, sex, body mass index, and blood pressure. A $p \leqslant 0.05$ was considered significant.

Result: Out of 120 participants, males were 61(51%), average BMI 22.36±2.65 kg/m², mean systolic and diastolic BP 113±8 mmHg and 74±6 mmHg. Work done dropped from 34.8 joules (no occlusion) to 30.8 joules (venous occlusion) and 23.8 joules (arterial occlusion). Fatigue onset time fell from 144 seconds (no occlusion) to 131 (venous occlusion) and 107 (arterial occlusion). Sex and BMI significantly influenced outcomes, females showing 4.7% higher work done under venous occlusion (p=0.01) compared to males, and underweight individuals experiencing delayed fatigue onset (p=0.012).

Conclusion: This study demonstrated the impact of altered blood flow on muscle performance and fatigability. Sex and BMI influenced muscle function.

How to cite

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Correspondence

Kalyan Gautam, Department of Physiology Kathmandu Medical College and Teaching Hospital, Nepal. Email: kalyangtmgtm@gmail.com, Telephone: +977 9841370087

Introduction

Myocytes form the fundamental units of muscle tissue, using specialized proteins to convert chemical energy into force for contraction and movement.[1] Muscle function is assessed by measuring work which in turn is influenced by various factors like age, sex, height, build of body, training, race, and motivation. Fatigue, a key feature of skeletal muscle, reduces its ability to generate force or power due to repetitive contractions, depending on work mode, duration and intensity.[2]

Muscle performance and fatigability are essential determinants of physical performance and recovery. Blood flow restriction (BFR) training has been studied increasingly for its influence on muscle endurance and strength. It has been applied predominantly in rehabilitation and sports settings but its mechanisms at localized muscle groups with varying levels of occlusion remain less researched.[3]

Previous researches had established that BFR exerted significant influences on muscle function and the development of fatigue via the control of oxygen delivery and metabolic accumulation.[4] This study aimed to investigate muscle function and fatigability under BFR using Mosso's ergography, a technique suited to measure work done and fatigue onset in controlled conditions. Young healthy undergraduate first year students at a medical college were selected as study participants. We sought to address the local paucity of data on how BFR influences muscle performance across normal, venous, and arterial occlusion states, while exploring the roles of BMI, MABP, and sex.

Method

A prospective study with repeated measures under multiple conditions (no occlusion, venous occlusion and arterial occlusion) was carried out. Young healthy students were taken as study participants. The study was conducted between 13 Apr 2023 and 05 Oct 2023 at Kathmandu Medical College and Teaching Hospital (KMCTH), Nepal. The study protocol was approved by the institutional review committee of KMCTH. Participants were selected using census sampling. A written informed consent was obtained from each subject.

Out of 156 students from first-year undergraduate medical, dental, and physiotherapy students, 120 students aged 19–22 years (61 males, 59 females) who consented to participate voluntarily were enrolled in study. Participants were selected through complete enumeration of all eligible and available individuals within the cohort involving a fixed population and employed a repeated-measures design. This was to reduce selection bias and enhance representativeness within the specified population. With a within-subject approach each participant served as their own control for assessment of muscular performance and fatigue levels, reducing the likely confounding influences of inter-individual variability.

Anthropometric measurements included height, weight and BMI. Hemodynamic measurements (systolic and diastolic blood pressures SBP, DBP and MABP) were determined using a standard sphygmomanometer (Brand: DOCTOR; made in Japan; make year: 2018; cuff size: 22-32 cm).

In this study we used Asia-Pacific BMI categorization (source: DOI)

	WHO (BMI)	**Asia-Pacific (BMI)**
Underweight	<18.5	<18.5
Normal	18.5–24.9	18.5–22.9
Overweight	25–29.9	23–24.9
Obese	≥30	≥25

Dominant hand forearm flexor muscles were assessed for work and fatigability by Mosso's Ergography.[5] The participants were asked to lift a load of 2 kg by middle finger of hand. In doing so, flexor muscles of forearm contracted. Mosso's ergography (Brand: Hepton Scientific and Laboratory Instrument, India; Make year: 2015) allowed isotonic or dynamic contraction of the muscles under normal conditions as well as

venous and arterial conditions. The BFR was induced by inflating the cuff of sphygmomanometer to the desired pressures.[6]

Different conditions chosen to assess muscle performance were:

- No occlusion/ Control condition (Condition 1): Initial work done (WD1) and fatigue onset time (FT1) were noted without restricting the blood flow to forearm flexor muscles.
- Venous Occlusion (Condition 2): After a 5 min rest, venous occlusion to forearm flexor muscles was induced by inflation of the cuff to 50 mmHg in the upper arm. Work done (WD2) and fatigue onset time (FT2) were recorded.
- Arterial Occlusion (Condition 3): After an additional 5 min rest, arterial occlusion to forearm flexor muscles was induced by inflation of the cuff to supra systolic pressure (>150 mmHg). Work done (WD3) and fatigue onset time (FT3) were recorded.

Muscle performance was measured as:

- Work Done (WD): The ergograms obtained from Mosso's Ergograph were used to measure work done for all three conditions (WD1, WD2, WD3).
- Fatigue Onset Time (FT): Fatigue onset time for all the conditions (FT1, FT2, FT3) were measured from the ergograms.
- Secondary parameters were hemodynamic (SBP, DBP, MABP) and anthropometric variables (height, weight, BMI).

Each participant underwent ergography under three sequential conditions with 5-minute rest intervals between trials. Ergograms obtained from each condition were used to assess work done and fatigue onset. The researchers themselves engaged in maneuvering the trials, whereas the lab supporters helped in the operation of Mosso's ergography. Approximately 20 minutes were required to obtain three ergograms for each participant. The trials were handled by all the researchers simultaneously. Working approximately for 3-4 hours a day, the entire data collection required over 10 days. Only one sphygmomanometer and only one Mosso's ergograph were used.

Statistical analysis was conducted using R Studio (version 4.2). Variables were normally distributed (Shapiro-Wilk test). Analyses were done to find out the relationship between two composite dependent variables- percentage change in work done for venous occlusion and arterial occlusion (%WD-V and %WD-A), and predictors including anthropometric (height, weight, BMI) and hemodynamic parameters (SBP, DBP, MABP), as well as demographics (age, sex).

Multiple linear regression (MLR) was employed to model the relationships between the selected predictors and the two dependent variables (%WD-V and %WD-A), for a simultaneous measure of multiple predictors and their interdependencies. For MLR, multicollinearity among predictors was assessed using variance inflation factor (VIF). All VIF values were below 5 (range: 1.2–3.8), indicating no significant multicollinearity issues.

Result

Out of a total 120 healthy young adult student participants males were 61(51%), most (95%) were of 19-21 years. Mean height was 1.67±0.08 m and mean weight 62±10 kg, average BMI 22.36±2.65 kg/m^2, 55% within normal, and 7.5% underweight. The mean systolic and diastolic blood pressures were 113±8 mmHg and 74±6 mmHg. The MABP was 87.2±6.2 mmHg, Table 1.

Muscle performance during venous and arterial occlusion conditions in terms of Work Done (WD) and Fatigue Time (FT) demonstrated a progressive decline across the three test conditions. Under no occlusion, i.e. control condition (WD1), the mean WD was 34.8±4.5 Joules, and decreased to 30.8±5.1 Joules under VO (WD2), and further dropped to 23.8±5.6 Joules under AO (WD3). Similarly, FT declined from 144±20 seconds under control to 131±19 seconds under VO, and to 107±17 seconds under AO, Table 2.

Females exhibited greater percentage changes in WD during VO (4.7%, p=0.01) and AO (7.2%, p=0.005) compared to males. Underweight individuals showed a significantly higher percentage change in WD during VO (8.5%, p=0.012) than those with normal BMI category. The effect was not statistically significant under AO, Table 3. Females showed slightly greater percentage changes in FT with both VO (2.2%) and AO (2.3%) than males. Underweight participants showed an increased percentage change (9.1%, p=0.004) in FT during VO compared to normal BMI. Underweight participants also showed an increased percentage change (7.8%) during AO compared to normal BMI group, but the increase was not significant (p=0.14), Table 3.

There was significant impact of BFR on both work performance and fatigue resistance, with AO producing more reduction in muscle function compared to VO. The WD vs. FT for all three conditions showed a positive relationship, i.e., greater work done with greater fatigue onset times, Figure 1.

Table 1. Undergraduate student characteristics in evaluation of blood flow restriction on muscle performance and fatigability using Mosso's Ergography, n=120

Variables	n(%)	mean±SD
Sex		
Male	61(51)	
Female	59(49)	
Age year		
19	30(25)	
20	47(39)	
21	37(31)	
22	6(5.0)	
Height meter		1.67±0.08
Weight kg		62±10
BMI		22.36±2.65
SBP		113±8
DBP		74±6
MABP		87.2±6.2
WD1		34.8±4.5
WD2		30.8±5.1
WD3		23.8±5.6
FT1		144±20
FT2		131±19
FT3		107±17
BMI Category		
Underweight	9(7.5)	
Normal	66(55)	
Overweight	26(22)	
Obese	19(16)	

Note: BMI-body mass index, SBP-systolic blood pressure, DBP-diastolic blood pressure, MABP-mean arterial blood pressure, WD1-work done by muscle at no occlusion, WD2-work done at venous occlusion, WD3-work done at arterial occlusion, FT1-muscle fatigue onset time at no occlusion, FT2- fatigue time at venous occlusion, FT3-fatigue time at arterial occlusion

Table 2. Multiple regression analyses for factors influencing percentage change in work done (WD) under venous occlusion (VO) and arterial occlusion (AO), n=120

Variables	% work change under VO (WD2-WD1/WD1)			% work change under AO (WD3-WD1/ WD1)		
	Reference	95% CI	p-value	Reference	95% CI	p-value
Age	-0.03	-2.0, 1.9	>0.9	-1.4	-4.1, 1.4	0.3
Sex						
Male	Reference			Reference		
Female	4.7	1.1, 8.2	0.01	7.2	2.2, 12	0.005
MABP	0.01	-0.31, 0.33	>0.9	-0.15	-0.60, 0.30	0.5
BMI						
Normal	Reference			Reference		
Obese	-0.52	-5.6, 4.6	0.8	-4.7	-12, 2.5	0.2
Overweight	-0.04	-4.3, 4.2	>0.9	-2	-8.1, 4.0	0.5
Underweight	8.5	1.9, 15	0.012	7	-2.3, 16	0.14

Table 3. Multiple regression analyses of factors influencing percentage change in fatigue onset time (FT), n=120

Characteristic	% fatigue change under VO, FT2-FT1/FT1			% fatigue change under AO, FT3-FT1/FT1		
	Reference	95% CI	p-value	Reference	95% CI	p-value
Age	0.3	-1.5, 2.1	0.7	-0.68	-3.7, 2.4	0.7
Sex						
Male	Reference			Reference		
Female	2.2	-1.1, 5.5	0.2	2.3	-3.3, 7.8	0.4
MABP	0.07	-0.23, 0.37	0.6	-0.21	-0.71, 0.28	0.4
BMI						
Normal	Reference			Reference		
Obese	-0.68	-5.5, 4.1	0.8	-4.3	-12, 3.7	0.3
Overweight	-1.9	-5.9, 2.1	0.3	-0.57	-7.3, 6.1	0.9
Underweight	9.1	3.0, 15	0.004	7.8	-2.5, 18	0.14

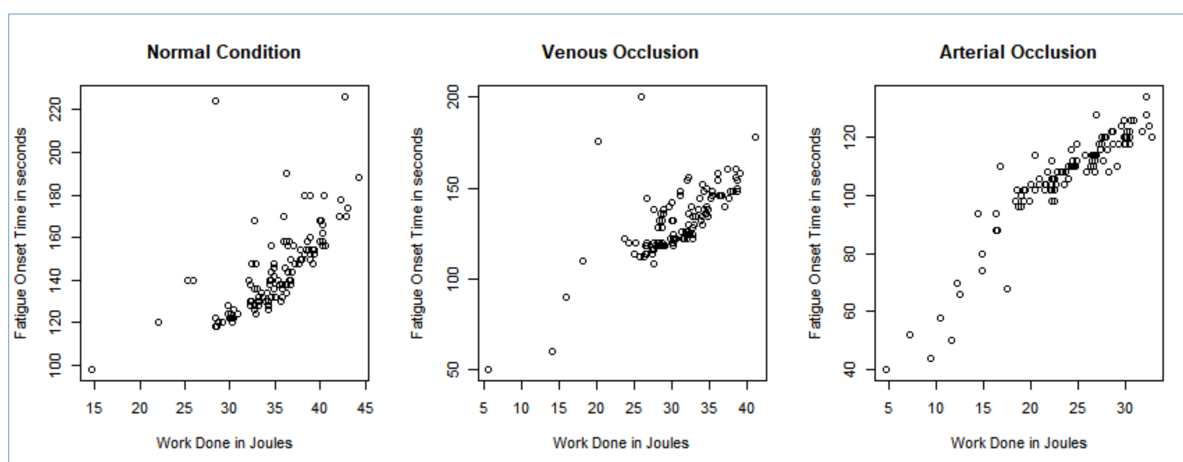

Figure 1. Scatter plots comparing Work Done (WD) and Fatigue Onset Time (FT), n=120

Discussion

The main finding of this study was that muscle performance, i.e. work done and fatigue onset time significantly decreased under venous and arterial occlusion compared to control (no occlusion) conditions, with variations influenced by gender and BMI

The results showed that females did better than males in both the extent of work done and the onset of fatigue in all experimental conditions. These findings closely match with a previous study which noted a delayed onset of fatigue and an earlier recovery of force generating capacity in women than in men during and following intermittent voluntary static contractions of the adductor pollicis muscle performed to exhaustion.[7] The improved performance of female respondents in the current study may also be because of the greater capacity for fatigue endurance, as described in previous research, which documented enhanced resistance to fatigue in females during longer isometric contractions.[8] This disparity is explained by muscle fibre composition discrepancies (greater ratio of fatigue-resistant Type I fibres in women), estrogen's protective effects on muscles, or variations in metabolic efficiency.

Increased vasodilatory responses of feed arteries to women's muscle can also enable women to compensate for muscle fatigue during isotonic contractions to a greater extent than men. For instance, vasodilatory responses of the femoral artery to dynamic knee extensor exercise were increased in women compared to men as observed from an earlier work by Parker et al. The increased vasodilatory response in women can increase muscle perfusion, reduce the buildup of metabolic byproducts, and perhaps delay the onset of muscle fatigue compared with men.[9]

It also emerged that muscle performance was significantly influenced by the BMI status. Individuals with underweight conditions presented the highest work done and longest onset time to fatigue across all conditions, while overweight and obese individuals did the least. This agrees with previous studies indicating that excess fat mass in overweight and obese people impairs the efficiency of their muscles and raises their metabolic demands in activities. Although cardiovascular strain increases linearly with increased BMI, being underweight may be advantageous because of lower metabolic demands and less body fat to enhance muscle efficiency and delayed onset of fatigue.[10,11]

Interesting enough, normal-weight subjects performed moderately and again proved the idea of optimal BMI being associated with better muscle function. These results are in agreement with those reported in a similar study, which noted that normal-weight individuals performed better, compared to overweight and obese individuals.[12] Furthermore, previous researches have shown that intramuscular fat secretes an inflammatory substance called adipokine interleukin- 6. Increased adipokine IL-6 secretion in overweight/ obese individuals, due to its inflammatory properties, might be associated with poorer physical performance.[13]

The decline in work done and earlier onset of fatigue seen under venous and arterial occlusion conditions in the present study have been consistent with other studies, which showed that restriction to blood flow blocks oxygen to the muscle, impairing oxidative metabolism, thus accelerating early fatigue.[14]

The relationship between different conditions of work done and the onset times of fatigue also emphasises the interaction that exists between the aerobic and anaerobic metabolic pathways. During a normal condition, the muscle shows the predominance of aerobic metabolism and thus higher work is done, with delays in onset of fatigue.

On the other hand, BFR shifts this scenario onto anaerobic metabolism and therefore leads to quicker energy reserve depletions and earlier onset of fatigue. These findings shows that the metabolic theories of muscle fatigue and energy supply-demand mismatches with BFR are contributors to the decline in performance.[15]

These results open up perspectives for further studies in the search for personalized strategies of exercise and rehabilitation, especially with regard to different anthropometric and physiological backgrounds.

Limitations of the study include that it was conducted among young healthy undergraduate students at a medical college in Kathmandu, and

may not reflect broader populations. Higher altitude of Kathmandu valley might influence muscle oxygenation differently than sea-level conditions. Limited resources restricted muscle function assessment to simple flexor evaluation using Mosso's ergograph, and only short-term muscle responses were measured. Factors like physical activity, diet, and hydration were not evaluated. Similarly, manual blood flow restriction via sphygmomanometer may lack precision. Additionally, the study used a fixed testing sequence (normal to venous occlusion to arterial occlusion) for consistency which may lead to order effects, such as learning or cumulative fatigue and may influence results.

Conclusion

The current study showed a progressive decrease in work performed and time to fatigue onset with the magnitude of blood flow restriction, indicating the physiological effect of venous and arterial occlusion on muscle function. This study demonstrated that muscle performance and fatigability were influenced by sex, BMI, and blood flow conditions, with superior performance in female and underweight participants, showing that muscle function is related to intricate physiological responses, including blood flow.

Author contribution

Conception, design: KG; Data acquisition: KG, GK, PKK; Data analysis, interpretation: KG; Drafting: KG, GK, PKK; Revision: KG, GK; Final approval of the version to be published: All; Agreement to be accountable for all aspects of the work: All.

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Conflict of interest

None

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Supplementary material

The data and supplementary material that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. Sweeney HL, Hammers DW. Muscle Contraction. Cold Spring Harbor Perspective in Biology. 2018 Feb 1;10(2):a023200. DOI PubMed Google scholar Full Text
2. Vøllestad NK. Measurement of human muscle fatigue. Journal of Neuroscience Methods. 1997 Jun 27;74(2):219–27. DOI PubMed Google Scholar
3. Burnley M, Jones AM. Power-duration relationship: Physiology, fatigue, and the limits of human performance. European Journal of Sport Science. 2018 Feb;18(1):1–12. DOI PubMed Google Scholar
4. Albert WJ, Wrigley AT, McLean RB, Sleivert GG. Sex differences in the rate of fatigue development and recovery. Dynamic Medicine. 2006 Jan 16;5:2. DOI PubMed Google Scholar Full Text
5. Di Giulio C, Daniele F, Tipton CM. Angelo Mosso and muscular fatigue: 116 years after the first Congress of Physiologists: IUPS commemoration. Advances in Physiology Education. 2006 Jun;30(2):51–7. DOI PubMed Google Scholar Full Text
6. Lorenz DS, Bailey L, Wilk KE, Mangine RE, Head P, Grindstaff TL, et al. Blood Flow Restriction Training. Journal of Athletic Training. 2021 Sep;56(9):937–44. DOI PubMed Google Scholar Full Text
7. Fulco CS, Rock PB, Muza SR, Lammi E, Cymerman A, Butterfield G, et al. Slower fatigue and faster recovery of the adductor pollicis muscle in women matched for strength with men. Acta Physiologica Scandinavica. 1999 Nov;167(3):233–9. DOI PubMed Google Scholar
8. Maughan RJ, Harmon M, Leiper JB, Sale D, Delman A. Endurance capacity of untrained males and females in isometric and dynamic muscular contractions. European Journal of Applied Physiology and Occupational Physiology.

1986;55(4):395–400. DOI PubMed Google Scholar

9. Parker BA, Smithmyer SL, Pelberg JA, Mishkin AD, Herr MD, Proctor DN. Sex differences in leg vasodilation during graded knee extensor exercise in young adults. Journal of Applied Physiology. 2007 Nov;103(5):1583–91. DOI PubMed Google Scholar Full Text
10. Fleck SJ, Kraemer WJ. Resistance Training: Physiological Responses and Adaptations (Part 2 of 4). The Physician and Sportsmedicine. 1988 Apr;16(4):108–24. DOI PubMed Google Scholar
11. Fleck SJ, Kraemer WJ. Resistance Training: Physiological Responses and Adaptations (Part 3 of 4). The Physician and Sportsmedicine. 1988 May;16(5):63–76. DOI PubMed Google Scholar
12. Ding C, Jiang Y. The Relationship between Body Mass Index and Physical Fitness among Chinese University Students: Results of a Longitudinal Study. Healthcare. 2020 Dec 17;8(4):570. DOI PubMed Google Scholar Full Text
13. Therkelsen KE, Pedley A, Hoffmann U, Fox CS, Murabito JM. Intramuscular fat and physical performance at the Framingham Heart Study. Age. 2016 Apr;38(2):31. DOI PubMed Google Scholar Full Text
14. Takarada Y, Takazawa H, Sato Y, Takebayashi S, Tanaka Y, Ishii N. Effects of resistance exercise combined with moderate vascular occlusion on muscular function in humans. Journal of Applied Physiology. 2000 Jun;88(6):2097–106. DOI PubMed Google Scholar Full Text
15. Allen DG, Lamb GD, Westerblad H. Skeletal muscle fatigue: cellular mechanisms. Physiological Reviews. 2008 Jan;88(1):287–332. DOI PubMed Google Scholar Full Text