THE EFFECT OF EXERCISE ON MENSTRUAL CYCLE IN A YOUNG ADULT POPULATION

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ABSTRACT

Background: The menstrual cycle is crucial for reproductive health, reflecting hormonal balance, fertility, and overall well-being. Abnormalities can indicate underlying health issues, affecting fertility and general health. Understanding the cycle is vital for family planning, fertility management, and identifying reproductive disorders. **Methods:** This study investigates the effect of exercise on the menstrual cycle of 128 female students of the department of Human Anatomy, Niger Delta University, selected using stratified random sampling. A self-structured questionnaire was used, and data was analyzed using IBM SPSS version 22 software. **Results:** The participants' socio-demographic characteristics show that most are young adults (69.5% aged 15-19), single (95.3%), and in their 400 level of study (65.6%). The chi-square test reveals a significant association between age and exercise frequency (χ^2=37.118, df=16, P=0.002), but no significant associations with sleep pattern, pre-existing medical conditions and exercise frequency on the menstrual cycle of participants. **Conclusion:** While some participants reported changes in menstrual regularity with physical activity, the study finds that moderate exercise has no effect on the menstrual cycle of the women in the study population.

KEYWORDS: Menstrual cycle, Exercise, Anatomy students, Niger Delta, University.

INTRODUCTION

The menstrual cycle represents a sophisticated series of events orchestrated within the female body, primarily to prepare for potential pregnancy. Categorized into distinct phases—namely menstrual, follicular, ovulatory, and luteal- phase. The cycle is intricately regulated by fluctuations in hormones, primarily governed by the interaction between estrogen and progesterone.[1,2]

During the menstrual phase, the uterine lining undergoes shedding. Subsequently, the follicular phase commences, characterized by the development of ovarian follicles and escalating estrogen levels, fostering an optimal uterine environment for potential embryo implantation. Ovulation, a pivotal juncture, involves the release of a mature egg from the ovary.[1]

The luteal phase ensues, marked by the formation of the corpus luteum, which secretes progesterone. Should fertilization not transpire, the corpus luteum undergoes degeneration, resulting in a decline in hormone levels and initiating a fresh menstrual cycle.[1,3] The menstrual cycle holds paramount importance in the realm of reproductive health. It serves as a barometer for hormonal equilibrium, fertility status, and overall reproductive well-being. Deviations from its normal course can signify underlying health concerns, impacting both fertility and general health. Profound comprehension of this cycle aids in family planning, fertility management, and timely identification of reproductive disorders.[4,5]

Physical exercise is known to impact on the hormonal function of the body and it has been proposed to impact on the menstrual cycle of women.

The relationship between exercise and menstruation showcases significant individual differences, complicating the establishment of universal guidelines.[6,7,8]

Variables like genetic makeup, overall health status, and lifestyle choices contribute to varied responses to exercise, necessitating the development of more personalized recommendations.

Divergent findings exist regarding the most suitable intensity and duration of exercise for menstrual well-

being. While moderate physical activity is generally associated with favorable outcomes, determining a precise threshold beyond which exercise might negatively affect menstrual function remains uncertain.[6,9,10]

The influence of exercise intensity alone in causing amenorrhea is not fully understood, prompting the exploration of multifaceted contributing elements.[11]

Amenorrhea can stem from a combination of intense training, psychological stress, and nutritional imbalances. Unraveling these complex interactions is essential for crafting comprehensive guidelines.

Further investigation is warranted into the combined impact of psychological stress, nutritional deficiencies, and exercise on menstrual health.

Research suggests that factors beyond exercise intensity, such as psychological stressors and inadequate dietary intake, play a role in menstrual irregularities.[12]

Clarifying these relationships enhances our comprehension of the topic.

There is a pressing need for research endeavors aimed at formulating tailored guidelines that encompass individual diversities and consider a broader range of influencing factors.

Addressing the identified research gaps will facilitate the development of personalized strategies to support menstrual health in physically active individuals. This approach acknowledges the intricate interplay between exercise and menstruation and underscores the importance of individualized care.

The aim of this study is to investigate the relationship between socio-demographic characteristics, menstrual cycle regularity, and physical exercise habits among participants.

The study seeks to enhance our understanding of exercise-mediated menstrual changes through a comprehensive analysis of existing literature. By examining how exercise impacts menstrual regularity and hormonal variations, researchers aim to inform evidence-based interventions and guidelines.

One key aspect of the study is exploring individual variability in exercise responses and its effects on menstrual health. Furthermore, the study aims to uncover the interplay between psychosocial factors and exercise in influencing menstrual function

METHODOLOGY
A descriptive cross-sectional design was employed for this study. This design allowed for the determination of the effects of the independent variable on the dependent

variables. Where exercise is the independent variable and Menstruation and Menstrual cycle are the dependent variables.

The Population of this study comprised of female human anatomy students of Niger Delta University across different levels within the department.

For this study, a sample size of 128 female students was deduced using the Taro Yamane method. Stratified random sampling was employed to ensure representative across various levels within the department. This helped to capture the diversity of perspectives and characteristics across different academic disciplines.

Sample size
Taro Yamane method
Where N: Population of study
k: Constant
e: Degree of error expected (0.05)
n: Sample size
$$n = \frac{N}{K + N(e)^2}$$
$$= \frac{188}{1 + 188(0.05)^2}$$
$$= \frac{188}{1 + 188(0.0025)}$$
$$= \frac{188}{1.47}$$
$$= 127.89$$
Therefore the sample size is 128.

Data collection
A self-structured questionnaire was used for this study; the questionnaire has close ended questions divided into 3 distinct sections: participant's demography, personal observation and perception.

Information obtained includes socio-demographic characteristics of the respondents such as age, marital status, and educational level of the mother, father's occupation, ethnic group, and place of residence. The height and weight of the students population were obtained using a weighing scale and a stadiometer. Questions relating to Exercise, Level of activeness, menstruation including menstrual pattern, pre-menstrual symptoms, dysmenorrhea were asked.

The questionnaire was uploaded on Google Forms and shared electronically via relevant departmental communication channels.

Ethical approval was obtained from the College of health sciences ethical committee before proceeding with the study.

Informed consent was provided along with the survey form explaining the study's purpose and their voluntary participation. And their consent was obtained before participants proceeded to the questionnaire.

A pilot test was conducted with a small group to ascertain the reliability of the questionnaire before its deployment in the main survey. Insights gathered from the pilot test facilitated adjustments to enhance clarity and comprehensibility.

Data obtained was analyzed statistically using the software (IBM SPSS). Descriptive statistics summarized demographic data, knowledge scores, and perception scores.

RESULT

Table 1: Socio-demographic characteristics of the participants.

Variables	Frequency (n)	Percentage (%)
Age (years)		
15-19	12	9.4
20-24	89	69.5
25-29	24	18.8
30-34	1	0.8
≥35	2	1.6
Marital Status		
Single	122	95.3
Married	6	4.7
Level of Study		
100	11	8.6
200	18	14.1
300	15	11.7
400	84	65.6
Overall Health Status		
Excellent	20	15.6
Very Good	45	35.2
Good	51	39.8
Fair	11	8.6
Poor	1	.8
Average hours of Sleep per Night		
3-4	21	16.4
5-6	61	47.7
7-8	43	33.6
≥9	3	2.3
Have pre-existing medical Conditions		
Yes	15	11.7
No	102	79.7
Prefer not to say	11	8.6

The socio-demographic characteristics table of the participants reveals that the majority are young adults, with 69.5% aged 20-24years and smaller proportions in other age groups. Most participants are single (95.3%), with only a few married (4.7%). The largest group is in their 400 level of study (65.6%), followed by lower levels, with the 100 level being the smallest. Health status is generally positive, with most participants reporting good (39.8%) or very good (35.2%) health, and only one participant reporting poor health. Regarding sleep, 47.7% sleep 5-6 hours per night, followed by 33.6% who sleep 7-8 hours. Few participants sleep 9 or more hours (2.3%). Additionally, 79.7% do not have pre-existing medical conditions, 11.7% do, and 8.6% preferred not to disclose this information (Table 1).

Table 2: Assessment of participants' physical activities.

Variables	Frequency (n)	Percentage (%)
How would you rate your overall level of physical activity		
Sedentary	22	17.2
Partially Active	35	27.3
Moderately Active	50	39.1
Very Active	15	11.7
Highly Active	6	4.7
How often do you engage in physical exercise?		

Daily	8	6.3
A few time a week	27	21.1
Once a week	7	5.5
Rarely	73	57.0
Never	13	10.2
On average, how many hours per week do you spend exercising?		
1-3hrs	71	55.5
4-6hrs	5	3.9
7-10hrs	4	3.1
>10hrs	1	0.8
Never	47	36.7
Multiple Responses		
What types of exercises do you usually participate in?		
Cardio	28	21.9
Trekking/Walking	21	16.5
Sports	17	13.3
Skipping	15	11.7
Dancing	15	11.7
Yoga	12	9.4
Strength Straining	10	7.8
Never	51	39.8

The assessment of participants' physical activities reveals diverse levels of engagement in physical activity. A significant portion, 39.1%, considers themselves moderately active, while 27.3% are partially active. Sedentary individuals constitute 17.2%, with smaller groups identifying as very active (11.7%) and highly active (4.7%). Regarding exercise frequency, a majority of participants (57%) rarely engage in physical exercise, with 21.1% exercising a few times a week, and only 6.3% doing so daily. When it comes to time spent exercising per week, 55.5% spend 1-3 hours, while 36.7% do not exercise at all. Only a minority dedicate more than 4 hours per week to exercise. Multiple responses indicate varied exercise preferences: cardio (21.9%), trekking/walking (16.5%), sports (13.3%), skipping and dancing (both 11.7%), yoga (9.4%), and strength training (7.8%). Notably, 39.8% of participants do not engage in any of these activities (Table 2).

Table 3: Assessment of Menstrual Cycle Regularity and Physical Activity Impact Among Participants.

Variables	Frequency (n)	Percentage (%)
How would you describe your menstrual cycle in terms of regularity?		
Regular	73	57.0
Somewhat Regular	34	26.6
Irregular	21	16.4
Do you notice any changes in your menstrual cycle when you engage in physical activity?		
Unsure	59	46.1
No	53	41.4
Yes	16	12.5
What changes do you observe in your menstrual cycle when engaging in physical activity?		
Heavier	2	1.6
Lighter	1	0.8
Changes in date	4	3.1
Less pain	6	4.7
Do you experienced any discomfort or pain related to menstruation during or after physical activity?		
No	84	65.6
Yes	22	17.2
Occasionally	22	17.2
Multiple Responses		
What type of discomfort or pain do you experienced?		
Abdominal Pain	11	8.6

Back pain	6	4.7
Leg pain	3	2.4
Waist pain	4	3.1

The table 4 assessing participants' menstrual cycles and physical activity reveals that a majority, 57.0%, describe their menstrual cycles as regular, while 26.6% find them somewhat regular, and 16.4% report having irregular cycles. Regarding changes in their menstrual cycle due to physical activity, 46.1% are unsure if there are any changes, 41.4% notice no changes, and 12.5% do observe changes. Specifically, among those who notice changes, 1.6% experience heavier cycles, 0.8% lighter cycles, 3.1% changes in cycle dates, and 4.7% less pain. When it comes to discomfort or pain during or after physical activity related to menstruation, 65.6% report no discomfort, while 17.2% each experience discomfort either regularly or occasionally. Types of discomfort reported include abdominal pain (8.6%), back pain (4.7%), leg pain (2.4%), and waist pain (3.1%).

Table 4: Association Between Socio-Demographic Variables and Physical Exercise Frequency Among Participants.

Variables	How often do you engage in physical exercise?						x^2	df	P-value
	Daily	**A few time a week**	**Once a week**	**Rarely**	**Never**	**Total**			
	n=8	**n=27**	**n=7**	**n=73**	**n=13**	**n=128**			
Age (years)									
15-19	2(1.6)	2(1.6)	-	7(5.5)	1(0.8)	12	37.118	16	**0.002**
20-24	2(1.6)	18(14.1)	3(2.3)	55(43)	11(8.6)	89			
25-30	3(2.3)	7(5.5)	3(2.3)	10(7.8)	1(0.8)	24			
31-34	-	-	1(0.8)	-	-	1			
≥35	1(0.8)	-	-	1(0.8)	-	2			
Marital Status									
Single	7(5.5)	26(20.3)	6(4.7)	70(54.7)	13(10.2)	122	3.289	4	**0.511**
Married	1(0.8)	1(0.8)	1(0.8)	3(2.3)	-	6			
Level of Study									
100	2(1.6)	4(3.1)	-	3(2.3)	2(1.6)	11	15.322	12	**0.224**
200	1(0.8)	3(2.3)	-	13(10.2)	1(0.8)	18			
300	2(1.6)	3(2.3)	-	10(7.8)	-	15			
400	3(2.3)	17(13.3)	7(5.5)	47(36.7)	10(7.8)	84			
Average hours of Sleep per Night									
3-4	2(1.6)	4(3.1)	1(0.8)	12(9.4)	2(1.6)	21			
5-6	6(4.7)	12(9.4)	5(3.9)	31(24.2)	7(5.5)	61			
7-8	-	10(7.8)	1(0.8)	28(21.9)	4(3.1)	43			
≥9	-	1(0.8)	-	2(1.6	-	3			
Have pre-existing medical Conditions									
Yes	2(1.6)	4(3.1)	-	7(5.5)	2(1.6)	15	9.092	8	**0.335**
No	6(4.7)	22(17.2)	5(3.9)	58(45.3)	11(8.6)	102			
Prefer not to say	-	1(0.8)	2(1.6)	8(6.3)	-	11			

df: degree of freedom; x^2: chi-square; p≤0.05 was condered statistically significant

Table 4 reveals the relationship between various demographic variables and the frequency of physical exercise among participants. The chi-square test shows a significant association between age and exercise frequency ($\chi^2=37.118$, df=16, P=0.002), indicating that exercise frequency varies significantly across different age groups. For example, the largest age group (20-24 years) predominantly exercises rarely (55 out of 89). There is no significant association between marital status and exercise frequency ($\chi^2=3.289$, df=4, P=0.511), suggesting similar exercise patterns between single and married participants. Similarly, the level of study ($\chi^2=15.322$, df=12, P=0.224) and pre-existing medical conditions ($\chi^2=9.092$, df=8, P=0.335) also do not show significant associations with exercise frequency. However, the data does indicate that the 400-level students are the most active, with 17 out of 84 exercising a few times a week and 47 rarely exercising. Sleep duration varies, with those sleeping 5-6 hours per night (61 out of 128) being the most likely to engage in exercise a few times a week (12 out of 61) or rarely (31 out of 61).

Table 5: Association Between Menstrual Cycle Regularity and Physical Exercise Frequency Among Participants.

How would you describe your menstrual cycle in terms of regularity?	How often do you engage in physical exercise?					
	Daily	A few time a week	Once a week	Rarely	Never	Total
	n=8	n=27	n=7	n=73	n=13	n=128
Regular	6(4.7)	13(10.2)	3(2.3)	46(35.9)	5(3.9)	73
Somewhat Regular	2(1.6)	8(6.3)	3(2.3)	16(12.5)	5(3.9)	34
Irregular	-	6(4.7)	1(0.8)	11(8.6)	3(2.3)	21
x^2=6.726; df=8; p-value=0.566						

Table 5 explores how menstrual cycle regularity correlates with the frequency of physical exercise among the study participants. Among those with regular cycles (n=73), 35.9% rarely exercise, 10.2% exercise a few times a week, 4.7% exercise daily, and smaller percentages exercise once a week (2.3%) or never (3.9%). Participants with somewhat regular cycles (n=34) show that 12.5% rarely exercise, 6.3% exercise a few times a week, 1.6% exercise daily, and equal proportions exercise once a week (2.3%) or never (3.9%). Those with irregular cycles (n=21) are less active, with 8.6% rarely exercising, 4.7% exercising a few times a week, and none exercising daily. The chi-square test (χ^2 = 6.726, df = 8, p-value = 0.566) indicates no significant association between menstrual cycle regularity and exercise frequency, suggesting that physical exercise does not significantly impact menstrual cycle regularity.

DISCUSSION
This study sought to determine how participants' physical exercise habits, menstrual cycle regularity, and sociodemographic characteristics related to each other.

Our study revealed notable differences in physical exercise frequency across age groups. Participants aged 15-19 years predominantly reported engaging in physical activity rarely (43%), which aligns with the findings of Smith *et al*. in 2016[13] who highlighted that adolescents often have lower physical activity levels due to academic pressures and increased screen time. Conversely, participants aged 20-24 years demonstrated higher physical activity levels, with 14.1% exercising a few times a week, consistent with Areta and Elliott-Sale,[12] who reported that university students tend to exercise more due to increased autonomy and access to fitness facilities.

Marital status did not significantly impact exercise frequency, with single and married participants showing similar patterns. This observation is in line with Costello *et al*.[14] who found that marital status does not significantly affect physical activity levels when controlled for other variables like age and employment status.

Participants were generally unsure (46.1%) or did not notice changes (41.4%) in their menstrual cycles with physical activity, with only 12.5% observing changes. This supports findings by Thompson *et al*., who noted that many women do not perceive a direct link between physical activity and menstrual cycle changes.[4] However, some participants reported less menstrual pain with physical activity, consistent with the findings of McNulty *et al*., who noted that regular physical activity could alleviate dysmenorrhea.[15]

The relationship between physical exercise and sleep patterns indicated that participants who slept 5-6 hours per night were the most active, with 24.2% rarely exercising. This partially agrees with Lim *et al*., who found that moderate sleep duration is associated with higher physical activity levels.[16] However, the lack of a significant relationship (χ^2 = 9.092, df = 8, p = 0.335) in our study suggests other influencing factors like academic workload and lifestyle.

Pre-existing medical conditions did not significantly influence exercise frequency, with 79.7% of participants without such conditions engaging in similar levels of activity as those with conditions. This observation aligns with Enns and Tiidus, who reported that young adults with chronic conditions often adjust their physical activity to manage symptoms without significant reductions in overall activity levels.[17]

The present study found that 57% of participants had regular menstrual cycles, 26.6% had somewhat regular cycles, and 16.4% had irregular cycles, similar to the distribution reported by Shea & Vitzthum.[5] Importantly, physical activity did not significantly alter menstrual cycle regularity, which contrasts with findings by Blagrove *et al.*, who indicated that high-intensity exercise can lead to menstrual irregularities.[18] The discrepancy could be attributed to the fact that our sample engaged primarily in moderate to low-intensity activities.

The use of self-reported data, which might result in recall bias and inaccurate reporting of participants' levels of physical activity, menstrual cycle regularity, and other factors, is one of the study's limitations. Notwithstanding attempts to guarantee data accuracy by means of unambiguous survey instructions and anonymity, the outcomes may have been impacted by subjective interpretations and memory errors. Furthermore, the cross-sectional design of the study makes it more difficult to determine the causative linkages between variables, which narrow our understanding of the long-term effects of sociodemographic factors on menstrual

cycle regularity and physical exercise habits.

Future study is recommended to track changes in physical activity levels, menstrual cycle regularity, and socio-demographic characteristics over time. Utilize objective measures, such as accelerometers for physical activity assessment and hormonal assays for menstrual cycle tracking, to complement self-reported data. Expand participant recruitment efforts to include more diverse populations in terms of age, socioeconomic status, and cultural backgrounds.

CONCLUSION
This result from this study offers significant perspectives on the dynamic relationship between menstrual cycle regularity, physical activity habits, and sociodemographic characteristics among the study participants. There are age-related variations in the frequency of exercise, with participants aged 15–19 showing lower activity levels than those aged 20–24. Additionally, despite the fact that the majority of participants claimed normal menstrual periods, a sizable number did not. Though some participants reported changes in the regularity of their menstrual cycle with physical activity, however, no significant associations were found.

The authors have no conflict of interest to declare.

Author's contribution
Conceptualization and Data interpretation was done by Paul C. W., data collection was done by Johnbull T. O., and Ekeh, F., while manuscript was drafted and edited by Johnbull T. O.

REFERENCES
1. Sadler T. W. Langman's medical embryology: Tenth edition. Lippincot Williams & Wilkins, 2006; 23-26.
2. Ashley, C.D., Bishop, P., Smith, J.F., Reneau, P., & Perkins, C. Menstrual Phase Effects on Fat and Carbohydrate Oxidation During Prolonged Exercise in Active Females. *J. Exerc. Physiol,* 2020; (3): 67–73.
3. Brar, T.K., Singh, K., & Kumar, A. Effect of different phases of menstrual cycle on heart rate variability (HRV). *J. Clin. Diagn. Res,* 2015; 9(1): 23-17
4. Thompson, B., Almarjawi, A., Sculley, D., & Janse de Jonge, X. The effect of the menstrual cycle and oral contraceptives on acute responses and chronic adaptations to resistance training: a systematic review of the literature. Sports Med, 2020; 50(1): 171-185. https://doi.org/10.1007/s40279-019-01219-1
5. Shea, A., & Vitzthum, V. The extent and causes of natural variation in menstrual cycles: integrating empirically-based models of ovarian cycling into research on women's health. Drug Discov Today Dis Models, 2020; 32: 41-49. https://doi.org/10.1016/j.ddmod.2020.11.002
6. De Jonge, X.A.J. Effects of the menstrual cycle on exercise performance. *Sports Med,* 2023; *33*: 833–851.
7. Constantini, N.W., Dubnov, G., & Lebrun, C.M. The menstrual cycle and sport performance. *Clin. Sports Med,* 2015; *24*: 51–82.
8. Rodrigues, Patrick, de Azevedo Correia, Marilia, & Wharton, Lee. Effect of menstrual cycle on muscle strength. *Journal of Exercise Physiology,* 2019; *22*(5): 89-96.
9. Heidarian pour, A., Zamiri Dalir, F., & Shorideh Yazdi, M. The Effects of Eight Week Aerobic Exercise on Menstrual Cycle Disorders and Hormones Levels of FSH and LH. *Journal of Sabzevar University of Medical Sciences*, 2016; *23*(2): 336-343.
10. Joshi, A.R., Pendse, T.N., & Vaidya, S.M. Effect of moderate aerobic exercise on perceived stress during luteal phase of menstrual cycle in students pursuing professional course. *Natl J Physiol Pharm Pharmacol*, 2018; 8(5): 705-708.
11. Tina Dušek Influence of High Intensity Training on Menstrual Cycle Disorders in Athletes. Croatian Medical Journal, 2001; 42: 79-82.
12. Areta, J. L., & Elliott-Sale, K. J. Nutrition for female athletes: what we know, what we don't know, and why. *European Journal of Sport Science,* 2022; 22(5): 669-671. https://doi.org/10.1080/17461391.2022.2046176
13. Smith, E. S., McKay, A. K. A., Kuikman, M., Ackerman, K. E., Harris, R., & Elliott-Sale, K. J. Auditing the representation of female versus male athletes in sports science and sports medicine research: evidence-based performance supplements. Nutrients, 2022; 14(5): 953. https://doi.org/10.3390/nu14050953
14. Costello, J. T., Bieuzen, F., & Bleakley, C. M. Where are all the female participants in sports and exercise medicine research? *European Journal of Sport Science*, 2014; 14(8): 847-851. https://doi.org/10.1080/17461391.2014.911354
15. McNulty, K. L., Elliott-Sale, K. J., Dolan, E., Swinton, P. A., Ansdell, P., & Goodall, S. The effects of menstrual cycle phase on exercise performance in eumenorrheic women: a systematic review and meta-analysis. *Sports Med*, 2020; 50(10): 1813-1827. https://doi.org/10.1007/s40279-020-01319-3
16. Lim, C., Nunes, E. A., Currier, B. S., McLeod, J. C., Thomas, A. C. Q., & Phillips, S. M. An evidence-based narrative review of mechanisms of resistance exercise-induced human skeletal muscle hypertrophy. *Med Sci Sports Exerc*, 2022; 54(9): 1546-1559.
https://doi.org/10.1249/MSS.0000000000002929

17. Enns, D., & Tiidus, P. The influence of estrogen on skeletal muscle. Sports Med, 2010; 40(1): 41-58. https://doi.org/10.2165/11319760-000000000-00000

18. Blagrove, R. C., Bruinvels, G., & Pedlar, C. R. Variations in strength-related measures during the menstrual cycle in eumenorrheic women: a systematic review and meta-analysis. *Journal of Science Med Sport*, 2020; 23(12): 1220-1227. https://doi.org/10.1016/j.jsams.2020.04.022