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Original Article

Nutritional modulation of blood pressure and vascular changes during severe menstrual cramps

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الملخص

أهداف البحث: في هذه الدراسة، قمنا باختبار تأثير التغذية على شدة الآم الحيض والتغيرات الوقتية المصاحبة لضغط الدم ومؤشرات صحة الأوعية الدموية. كما فحصنا أيضا تأثير التغذية على الأنجيوتنسين وجزيء التصاق الخلايا الوعائية.

طرق البحث: تم توزيع ٢٠٧ طالبة جامعية أعمارهن بين ١٨-٢٥ عاما، على مجموعات. مجموعة بدون عسر حيض (التحكم)، ومجموعة عسر الحيض المعتدل، وعسر الحيض الشديد باستخدام مقياس مستويات إن آر إس-١١ اوكونتاكتن -١ المبدئي. وتم تغذية المجموعات بشكل منفصل بوجبات الخضروات، والبروتين، والكربوهيدرات. تتضمن خطة الوجبة ثلاثة أنواع مختلفة من الأطعمة التي تقدم ثلاث مرات يوميا (الفطور والغذاء والعشاء) التي تبدأ ٤٨ ساعة قبل الحيض.

النتائج: وجدنا أن ٧٣.٩٪ و١٠٠٪ من المريضات في مجموعة عسر الحيض المعتدل اللاتي كان غذائهن البروتين والكربوهيدرات أصبح لديهن عسر الحيض الشديد. في حين ٦٩.٦٪ من مريضات عسر الحيض الشديد على الخضروات لم يصبح لديهن عسر الحيض وأصبح ضغط الدم عند ٦١٪ من عسر الحيض الشديد طبيعيا للقيم القياسية ١٢٠/ ٨٠. وأصبح ضغط الدم الانقباضي عند ٨٧٪ من اللاتي لديهن عسر الحيض المعتدل ≤ ١٣٠ والانبساطي ≤ ٩٠ بعد وجبة الكربوهيدرات. من ناحية أخرى، ٣٠٪ من مجموعة عسر الحيض الشديد أصبح لديهن ضغط الدم أعلى بعد وجبة البروتين. فيما يتعلق باختيار الوجبة، كانت شدة الآم الحيض مرتبطة بشكل إيجابي مع الأنجيوتنسين وجزيء التصاق الخلايا الوعائية. بالمثل، كان جزيء التصاق الخلايا الوعائية مرتفعا بشكل ملحوظ في المشاركات بعسر الحيض. وكان متوسط المستويات لجزيء التصاق الخلايا الوعائية والأنجيوتنسين عند المشاركات بعسر الحيض اللاتي على وجبات الخضروات مقاربة للمستويات الأساسية لمجموعة التحكم.

الاستنتاجات: توصي هذه الدراسة بتناول وجبة نباتية ٤٨ ساعة على الأقل قبل الحيض كنهج غذائي فعال لمنع وعلاج تقلصات الدورة الشهرية الشديدة. ويمكن هذا النهج أيضا منع تغيرات الأوعية الدموية المصاحبة، في حين أنه يجب تجنب الوجبات الكربوهيدراتية ٤٨ ساعة على الأقل قبل الحيض.

الكلمات المفتاحية: ضغط الدم؛ عسر الحيض؛ التغذية؛ الألم؛ الأوعية الدموية

Abstract

Objectives: This study examined the influence of nutrition on the severity of menstrual pains and associated transient changes in blood pressure (BP) and vascular-health indicators. It has also investigated the influence of nutrition on angiotensin (ANG II) and vascular cell adhesion molecules (VCAM-1).

Methods: A total of 207 university students, aged between 18 and 25 years, were grouped into three groups: a no-dysmenorrhoea (control) group, a moderate dysmenorrhoea (MDys) group, and a severe dysmenorrhoea (SDys) group, using the NRS-11 scale and initial contactin-1 (CNTN-1) levels. The groups were separately fed vegetable, protein, and carbohydrate meals. The meal plan involved three different types of food served three times a day (for breakfast, lunch, and dinner), beginning 48 h before menstruation.

Results: We found that 73.9% and 100% of the MDys patients on the protein and carbohydrate diets, respectively, had severe dysmenorrhoea. As many as 69.6% of the SDys patients on vegetable diets experienced no dysmenorrhoea; the BP of 61% of SDys normalised to the standard values of 120/80. The BP of 87% MDys had systolic BP $\geq$ 130 and $\geq$90 diastolic BP after carbohydrate meals. On the other hand, 30% of SDys had higher BP after protein meals. With respect to the choice of

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food, the severity of menstrual pain was positively correlated with ANG II ($r = 0.5158$) and VCAM-1 ($r = 0.5849$). ANG-II. Similarly, VCAM-1 were significantly elevated ($p < 0.05$) in the dysmenorrhoeal participants. The mean VCAM-1 and ANG-II levels of dysmenorrhoeal participants placed on vegetable meals were comparable to the control baseline levels.

Conclusions: This study recommends the intake of a vegetable meal at least 48 h before menstruation as an effective nutritional approach to preventing and managing severe menstrual cramps. This approach can also prevent associated vascular changes. Carbohydrate meals should be avoided at least 48 h before menstruation.

Keywords: Blood pressure; Dysmenorrhoea; Nutrition; Pain; Vascular

Introduction

Severe pain causes distress and discomfort, which can lead to high blood pressure and vascular damage, among other complications.[1−3] There are several causes of pain in the form of conscious or non-conscious infliction. For women, painful menstrual episodes, otherwise known as dysmenorrhoea, have become an overarching gynaecological problem facing premenopausal women of reproductive age, and primarily young women.[4] The continuous link between painful menstrual cramps and changes in the vascular system has become alarming.[5−7] Other common outcomes associated with dysmenorrhoea include mood swings, meal skipping, weight loss, and an overall public-health burden.[8,9] These outcomes and associated complications continue to receive little serious attention for two main reasons: the perception that menstrual episodes are a normal occurrence, and the difficulties associated with measuring pain symptomatology.[10] Most studies do not clearly distinguish between mild, moderate, and severe dysmenorrhoea because there is no biomarker capable of reliably measuring the severity of menstrual pain. For this reason, researchers rely on descriptions, provided by affected individuals, of the extent to which their dysmenorrhoea interferes with daily activities. A study has now made the association between dysmenorrhoea and the expression of contactin-1 levels.[11] Contactin-1 is a biomarker in the immunoglobulin family, whose expression has been identified in both vasculogenesis and pain sensation.[11] Contactin-1 expressions are associated with the over-secretion of angiotensin-1 and vascular cell adhesion molecules, which are reliable diagnostic biomarkers for vascular health.[11] At the same time, the 'normal' perception of dysmenorrhoea and its attendant complications, caused by pain-relief drugs, including sodium diclofenac and ibuprofen,[12] discourages dysmenorrhoeal women from continuing with pharmacological interventions. Other well-documented non-pharmacological methods of relieving menstrual pain include diet interventions, lifestyle adaptations, herbs, and natural supplements.[10] Studies that show the impact of diet on menstrual outcomes have lacked consistency; there are no widely accepted recommended dietary habits for dysmenorrhoea.[13] However, some Cochrane reviews have summarised the importance and safety of using targeted premenstrual food choices to manage painful menstrual episodes.[14] It is clear that dietary habits and their association with dysmenorrhoeal outcomes should receive more attention. Foods such as eggs and fish and foods containing calcium[16] and oils rich in omega 3 fatty acids[15] have been found to ameliorate menstrual cramp by stimulating prostaglandin. Vegetables and antioxidants, such as vitamin E, may also help to manage dysmenorrhoea.[14,17,18] Although researchers have recognised that consuming single foods can have an obvious positive outcome, the methods and concepts used in these studies have substantial limitations because foods are consumed as meals, which form dietary patterns, rather than as isolated food items.[19] To address this issue, the present study has adopted a design that provides a dietary intervention throughout the period of menstrual flow, beginning 48 h before any menstrual symptoms. In this way, it provides authoritative information on the impact of premenstrual diet on dysmenorrhoea-related complications. Undergraduate students between 18 and 25 years old were recruited for a controlled clinical study that spanned four menstrual cycles. The subjects were placed on dietary interventions involving vegetables, proteins, and carbohydrates. Afterwards, the expression of the pain biomarker contactin-1 was correlated with any eventual pain. In addition, their vascular health was measured through blood-pressure measurements and the activities of angiotensin-II and vascular cell adhesion molecule-1.

Materials and Methods

This study was a non-randomised controlled clinical trial involving 381 female university students. The study was approved by the Institutional Ethics Board, which issued an ethical approval number, IMSU/BCH/ETS/20190710. All participants provided written consent to participate. The inclusion criteria were as follows: participants had to be available for three months, have regular menstrual cycles, and use no pain relief for 2 months before and during the entire study. The study spanned a total of 4 months and the first month's menstrual flow was observational, allowing participants to follow their normal diets prior to menstrual flow. The feeding trial spanned three consecutive menstrual cycles.

Data collection

All 381 participants provided blood samples for an initial assessment of their contactin-1 levels; based on this and their NRS-11 (Numeric Rating Scale − II), the participants were assigned to study groups. The results obtained at this stage were used as the baseline results.

The NRS-11 scale is similar to Ozerdogan's verbal multidimensional scoring system.[20] It is used to measure the severity of menstrual pain, having being validated by

Bourdel et al.,[21] as one of the most effective scales for measuring endometrioses-related pain. The scale contains four strata: 0 for no dysmenorrhoea, 1−3 for mild dysmenorrhoea, 4−6 for moderate dysmenorrhoea, and 7−10 for severe dysmenorrhoea.

A preliminary screening of the 381 participants showed the following:

77 students selected the 0 pain scale, with the range of contactin-1 levels at 7.30−9.40 ng/ml.

159 students selected the 1−3 pain scale, with the range of contactin-1 levels at 9.20−17.60 ng/ml.

69 students selected the 4−6 pain scale, with the range of contactin-1 levels at 18.10−35.20 ng/ml.

76 students selected the 7−10 pain scale, with the range of contactin-1 levels at 38.20−54.10 ng/ml.

The data were stratified and the minimum number of students recorded for any group was applied uniformly across all study groups in this study. Each group had a uniform number of 69 participants.

The study involved three experimental groups: the non-dysmenorrhoea, moderate dysmenorrhoea, and severe dysmenorrhoea groups, as detailed below in Figure 1:

Feeding trial and laboratory analysis

A set of three different meals was administered daily for breakfast, lunch, and dinner for two days before and throughout the menstrual flow.

The meals involved vegetables, proteins, and carbohydrates, the foods that predominated in the dietary habits of study participants.

The vegetable meal involved okra (*Abelmoschus esculentus*) for breakfast, cabbage (*Brassica oleracea*) for lunch, and pumpkin leaves (*Telfairia occidentalis*) for dinner.

The protein meal involved boiled white kidney beans (*Phaseolus vulgaris*) and tea (milk in water) for breakfast, ground beef for lunch, and a ground fish (*Silurus glanis*) and chicken or egg meal for dinner.

The carbohydrate meal involved sweetened bread for breakfast, boiled corn for lunch, and boiled yam for dinner.

To make each meal palatable, a small amount of sauce, made from 2 g of onions, 50 g of sliced tomatoes, and 2 g of salt, was included with each meal. All of the meals were served once per mealtime; they were prepared and provided by the researchers after focus-group discussions. By consensus, the size of each meal averaged 100 g per serving across all meals.

At the end of each menstrual period, the participants were allowed to revert to their normal feeding habits and patterns.

For the dysmenorrhoeal participants, blood samples were collected on the second day of dysmenorrhoea (participants indicated the most intense period of dysmenorrhoea), while for the normal control participants, blood samples were collected on the last day of the feeding trial. The researchers used ELISA kits to analyse blood samples for ontactin-1, angiotensin-II, and Vascular Cell Adhesion Molecule −1 activities, as described in their assay manuals. The participants' blood pressure was obtained using an analogue sphygmomanometer.

Statistical analysis

The demographic data were presented as ranges and mean ± standard deviations, using SPSS Version 20 software. A Shapiro−Wilk test was carried out to confirm the normality of distribution. Graph Pad Prism 7 was used to conduct a Pearson's correlation to determine the relationship between the pain scale and contactin-1 levels, as well as the relationship between foods consumed during menstruation and the participants' ANG-II and VCAM-II levels. A one way ANOVA was used to individually compare the data for CNTN-I, ANG-II, and VCAM-1 for the control baseline, the dysmenorrhoea baseline, and the 1st and 3rd month periods. Blood-pressure data obtained before the feeding trial and at the third month were presented using a frequency-distribution table. The ANG-II and VCAM-1 data were presented as mean ± standard deviations in a Graph Pad Prism 7 bar chart.

Results

The participants in this study were 18−25 years old; their menarche occurred between 11 and 15 years, as shown in Table 1. The participants first experienced dysmenorrhoea when they were 12−15 years old, with episodes lasting 2.45 ± 0.50 days, on average. The body-mass index (BMI) range for the normal and moderate dysmenorrhoeal participants was between 18.74−34.20 and 19.60−31.58 kg/m^2 respectively, while the severe dysmenorrhoeal participants had a BMI range of 19.10−30.90 kg/m^2.

In Table 2, the consumption of vegetables and protein-rich foods 48 h before menstrual flow produced no significant effect ($p > 0.05$) on the non-dysmenorrhoeal participants for the 1st and 3rd months, while CNTN-1 levels were significantly elevated ($p = 0.0482$) at the 3rd month. Participants in the moderate group who had vegetable meals prior to the first flow, showed significantly lower ($p < 0.05$) CNTN-1 levels, relative to the moderate dysmenorrhoea baseline; after 3 months, their mean CNTN-1 levels were equivalent to the non-dysmenorrhoeal baseline. Of the students who reported moderate dysmenorrhoea, 82% experienced mild dysmenorrhoea after the first month on premenstrual vegetable meals, while 17.4% remained non-responsive. After the third consecutive menstrual cycle, 69.6% of participants changed to the no-dysmenorrhoea category, while 30.4% were mildly dysmenorrhoeal. Among participants in the severe dysmenorrhoea category who consumed vegetables during the first month, 56.5% changed to mild dysmenorrhoea, 30.5% were moderately dysmenorrhoeal, and 13.0% remained severely dysmenorrhoeal. After 3 months, 56.5% changed to the no-dysmenorrhoea category, while 34.8% and 8.7% respectively were mildly and moderately dysmenorrhoeal. There were statistically significant changes in mean differences in the CNTN-1 levels of severely dysmenorrhoeal participants fed on vegetables, in comparison to their baselines. All participants in the moderate-dysmenorrhoea category who had protein meals remained moderately dysmenorrhoeal after the first month; after the third month, 26.1% were still
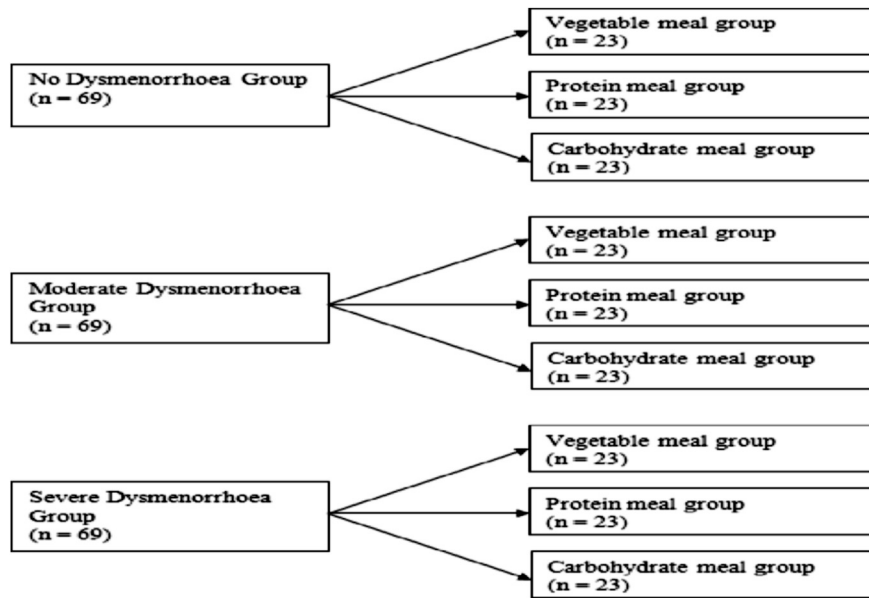
Figure 1: Experimental groups of participants.

moderately dysmenorrhoeal and 73.9% became severely dysmenorrhoeal. All participants in the severe dysmenorrhoea category who ate protein meals remained severely dysmenorrhoeal. The mean CNTN-1 levels of moderately dysmenorrhoeal participants who ate carbohydrate meals for a month and up to 3 months were statistically equivalent to the mean levels of the severely dysmenorrhoea baselines. All participants (100%) in the moderate and severe dysmenorrhoea categories who had carbohydrate meals were severely dysmenorrhoeal after the first month and over the 3-month period.

Table 3 shows the blood-pressure levels (BP) of study participants after the third month of the study. Before the feeding trials, 22 participants in the no-dysmenorrhoea category who ate vegetables had baseline systolic/diastolic BP of 120/80 mmHg, while one participant had 120/70 mm/Hg. All participants who ate protein and carbohydrate meals had baseline BP of 120/80 mmHg. After the vegetable meal, all 23 non-dysmenorrhoeal participants eventually recorded 120/80 mmHg BP. Exactly 21 participants had 120/80 mmHg and 2 participants had 130/80 after the protein meal. After the carbohydrate meal, 1 participant had 120/70 mmHg; 14 participants had 120/80 mmHg; 2 participants had 120/90 mmHg; and 3 each had 130/80 and 130/90 mmHg. After the vegetable meal during severe dysmenorrhoea, most (14) participants had 120/80 mmHg BP, while the majority (15

severely dysmenorrhoeal participants) of those who ate protein meals had 130/90. None of the severely dysmenorrhoeal students who had carbohydrate meals recorded below 130 mmHg systolic and 80 mmHg diastolic BP; 19 participants had ≥ 90 mmHg diastolic BP and 7 participants recorded 150 mmHg systolic BP.

A positive correlation ($r = 0.5158$, $p < 0.0001$) was established between the participants' food options and dysmenorrhoeal participants' ANG-II (Figure 2a) levels. The baseline ANG-II levels of mildly and severely dysmenorrhoeal participants were significantly higher than those of non-dysmenorrhoeal/control participants in all food categories (Figure 2b). The reversal of levels of ANG-II in the moderate and severe dysmenorrhoea groups after their 48-hr premenstrual vegetable meals during the 1st and 3rd months was statistically comparable ($p < 0.05$) to the control baseline. Eating protein meals did not produce any significant change in either the severe or moderate groups after the 1st and 3rd months. After the 1st month, the mean levels of ANG-II levels among severely dysmenorrhoeal participants were similar to the severe dysmenorrhoea baseline ANG-II levels. The elevations in the mean ANG-II levels of the dysmenorrhoeal participants who ate carbohydrate meals were statistically significant. The relationship between premenstrual food choice and VCAM-1 levels is presented in Figure 2c, while the mean VCAM-1 of the dysmenorrhoeal

Table 1: Demographic characteristics of participants.

Parameters	Normal (n = 69)	Moderately painful (n = 69)	Severely painful (n = 69)
Age (yrs)	18−24 (21.40 ± 2.2)	18−24 (19.50 ± 2.62)	18−25 (20.80 ± 2.0)
Menarche (yrs)	12−14 (12.50 ± 0.50)	12−15 (12.45 ± 0.60)	11−15 (12.80 ± 0.70)
Age of first dysmenorrhoea (yrs)	−	12−15 (13.26 ± 1.10)	12−15 (13.84 ± 1.4)
Duration of Dysmenorrhoea (days)	−	2−3 (2.45 ± 0.50)	2−3 (2.45 ± 0.50)
BMI (kg/m^2)	18.74−34.20 (27.60 ± 4.82)	19.60−31.58 (25.39 ± 6.38)	19.10−30.90 (24.22 ± 5.73)

BMI − body-mass index, note: (mean ± standard deviations) represents the numbers between brackets in the tables.

Table 2: Contactin-1 (ng/ml) levels of control and dysmenorrhoeal participants fed 48 h before dysmenorrhoea for 3 months.

Foods	No dysmenorrhoea n = 69			Moderate Dysmenorrhoea n = 69			Severe Dysmenorrhoea n = 69		
	Baseline	1st Month	3rd Month	Baseline	1st Month	3rd Month	Baseline	1st Month	3rd Month
Vegetables	8.31 ± 0.71 (7.30 −9.40)	8.09 ± 0.64 (7.30 −9.10)	8.05 ± 0.69 (7.10 −9.10)	27.48 ± 3.87 (20.60 −35.20)	16.98 ± 4.78[#] (11.60 −29.30)	9.61 ± 2.37** (7.10 −15.40)	45.68 ± 4.74 (38.50 −52.80)	22.93 ± 8.54* (14.00 −41.40)	11.23 ± 4.56** (7.20 −24.10)
C−N -D (%)		−	−		−	69.6		−	56.5
C-Mi-D (%)		−	−		82.6	30.4		56.5	34.8
C−Mo-D (%)		−	−		17.4	−		30.5	8.7
C−S-D (%)		−	−		−	−		13.0	−
Proteins	8.10 ± 0.63 (7.10 −9.10)	8.13 ± 0.74 (7.20 −9.20)	8.06 ± 0.72 (7.10 −9.20)	25.15 ± 4.66 (18.10 −32.70)	27.62 ± 4.36 (20.40 −37.20)	37.32 ± 6.15 (26.30 −51.20)	46.35 ± 4.49 (39.80 −53.40)	48.73 ± 3.91 (40.60 −55.20)	52.43 ± 4.86 (44.90 −61.90)
C−N -D (%)		−	−	−	−	−		−	−
C-Mi-D (%)		−	−	−	−	−		−	−
C−Mo-D (%)		−	−	−	100	26.1		−	−
C−S-D (%)		−	−	−	−	73.9		100	100
Carbohydrates	8.35 ± 0.67 (7.50 −9.60)	8.23 ± 0.75 (7.30 −9.20)	11.48 ± 5.5*[#] (7.40 −21.70)	26.61 ± 4.71 (17.40 −34.20)	46.42 ± 4.85[##] (38.60 −54.50)	48.17 ± 4.93[##] (41.20 −60.50)	45.76 ± 4.85 (38.20 −54.10)	53.86 ± 5.15 (48.60 −65.30)	58.69 ± 5.34 (49.20 −67.40)
C−N -D (%)		−	−	−	−	−		−	−
C-Mi-D (%)		−	20	−	−	−		−	−
C−Mo-D (%)		−	20	−	−	−		−	−
C−S-D (%)		−	−	−	100	100		100	100

Note: (mean ± standard deviations) represents the numbers between brackets in the tables. C−N-D − Change to no dysmenorrhoea, C-Mi-D − Change to mild dysmenorrhoea, C−Mo−D − Change to moderate dysmenorrhoea, C−S-D − Change to severe dysmenorrhoea, # - Significantly lower than the moderate dysmenorrhoea baseline but higher than the control baseline, ## - Comparable to the severe dysmenorrhoea baseline, * - Significantly lower than the severe dysmenorrhoea baseline but higher than the control baseline, **- No significant difference from the control baseline, *# - Significantly higher than the control baseline.

Table 3: Third month blood-pressure frequency table; dysmenorrhoeal participants ate 48hrs before dysmenorrhoea for 3 months.

| BP (mm/Hg)	Number of participants (%)					
	Control		Moderate Dysmenorrhoea		Severe Dysmenorrhoea	
	Baseline	3rd Month	Baseline	3rd Month	Baseline	3rd Month
Vegetables						
120/70	4	0	−	0	0	0
120/80	96	100	39	43	0	61
120/90	0	0	9	5	9	9
130/80	0	0	13	43	0	17
130/90	0	0	39	9	61	13
140/90	0	0	0	0	26	0
140/100	0	0	0	0	4	0
Proteins						
120/80	100	92	26	31	0	0
120/90	0	0	17	13	22	17
130/80	0	9	31	17	9	0
130/90	0	0	26	39	56	65
140/90	0	0	0	0	13	18
Carbohydrates						
120/70	0	4	0	0	0	0
120/80	100	61	22	9	4	0
120/90	0	9	26	4	9	0
130/80	0	13	35	17	22	17
130/90	0	13	17	44	48	22
140/90	0	0	0	17	17	17
140/100	0	0	0	0	0	13
150/90	0	0	0	0	0	9
150/100	0	0	0	9	0	22

BP − Blood pressure.
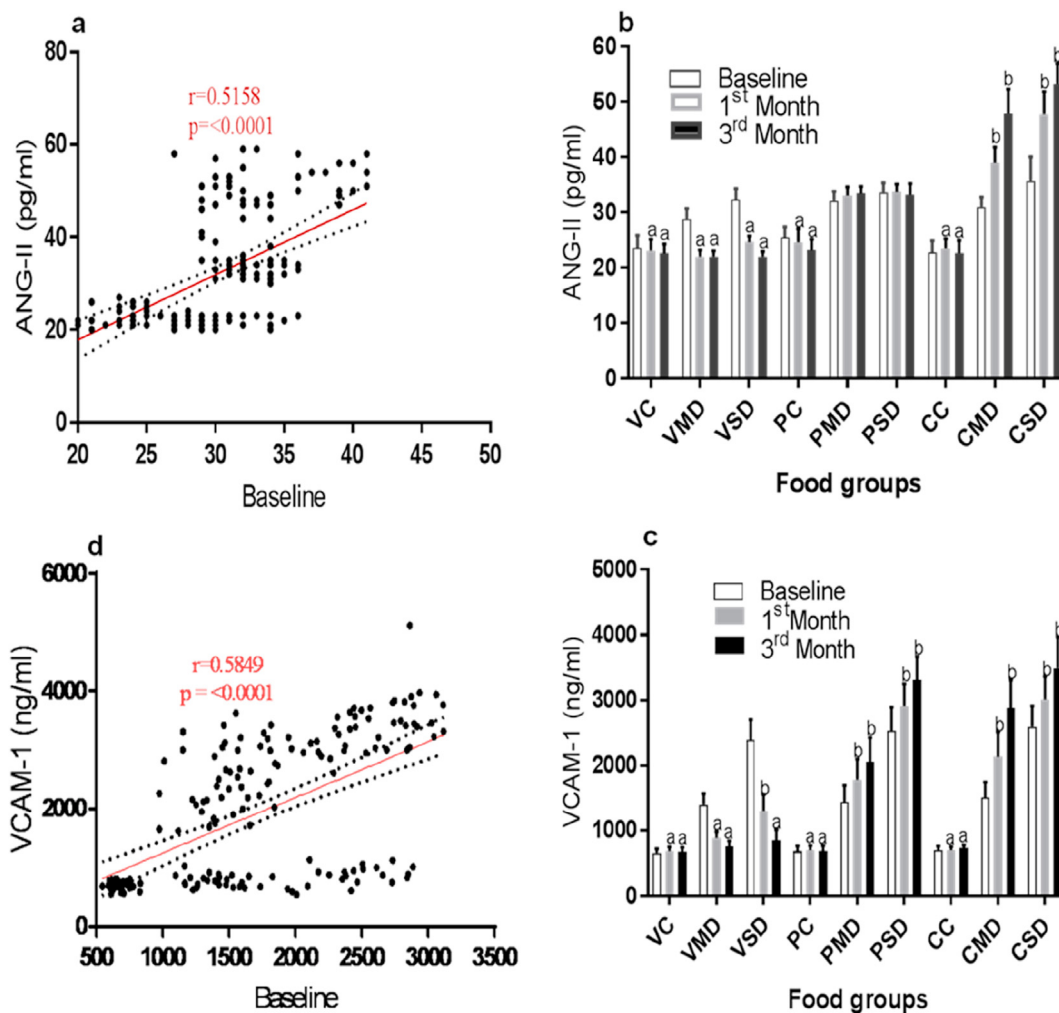
Figure 2: a) Correlation graph showing ANG-II levels at baseline and the 3rd month levels in intervention groups; b) Mean ANG-II levels of control and dysmenorrhoeal participants by 48-hr pre-menstrual choice of food; c) correlation graph showing VCAM-1 levels at baseline and at the 3rd month across the intervention groups; d) Mean VCAM-1 levels of control and dysmenorrhoeal participants by 48-hr pre-menstrual choice of food. Baseline − measurement for all intervention groups: a − no significant difference with the control baseline; b − significantly higher than the control baseline.

groups is presented in Figure 2d. The scatter plot shows a positive correlation (r = 0.5849, $p < 0.0001$) between the premenstrual food choice and VCAM-1 levels. Participants in the moderate and severe dysmenorrhoeal groups who ate protein or carbohydrates showed a significant increase in VCAM-1, relative to the dysmenorrhoea and control baselines. The VCAM-1 levels of participants who ate vegetable meals in the moderate and severe dysmenorrhoea groups were comparable to the control baseline.

Discussion

Foods consumed prior to or during menstruation influence menstrual outcome.[10,11,22] Among the reported outcomes of dysmenorrhoea are blood-pressure distortion and vascular health.[23,24] However, the degree to which certain foods influence dysmenorrhoea and related outcomes is unscalable, given the lack of reliable biomarkers to classify dysmenorrhoea according to

severity of pain. Previous studies have used factors such as skipping breakfast to measure the severity of dysmenorrhoea,[25−27] and while these methods present interesting perspectives, they cannot quantify pain intensity. A positive correlation between the severity of menstrual pain, as indicated in a distributed NRS-II scale, and the participants' contactin-1 levels makes it possible to assess the influence of 48 h of premenstrual consumption of vegetables, proteins, and carbohydrates on the severity and outcomes of dysmenorrhoea. The demographic characteristics of all participants were within the range to regulate any influence on dysmenorrhoea. Our results show that 40% of women who do not experience menstrual pain are likely to experience mild or moderate dysmenorrhoea after the extended premenstrual consumption of carbohydrates; 100% of women who initially experience mild dysmenorrhoea are likely to experience severe dysmenorrhoea. In earlier studies, which had smaller sample sizes and lacked well-controlled participants, the consumption of pasta and

cereals has been associated with higher levels of menstrual pain[28]. The lack of well-controlled participants and the inability to completely exclude other diets, merely drawing inferences from the fact that carbohydrates constituted the predominant diet in the days before menstruation, may have influenced the outcomes of studies including Dicintio et al.,[11] Tavallaee et al.,[29] with Iranian women, and Gagua et al.,[13] with Georgian women. Protein diets did not have a significant impact on menstrual-flow severity in most participants, except when proteins were consumed over three continuous menstrual cycles. However, the use of vegetables to reduce menstrual pain has been reported in several studies.[22,28,30] The daily and consistent consumption of vegetables is associated with reduced levels of dysmenorrhoea.[29] In the present study, up to 91% of severely dysmenorrhoeal participants experienced mild to no dysmenorrhoea after premenstrually consuming vegetable-based foods for 3 consecutive menstrual cycles. This may be due to the anti-inflammatory effect of the carotenoids in green vegetables[31] or the stimulation of sex hormones, particularly prostaglandins and oestrogen.[30] Vegetarians have also been reported to express higher activities of serum sex-hormone binding globulin (SHBG).[32] Blood-pressure changes are a commonly noticed outcome of dysmenorrhoea. Moreover, it is well known that pain elevates resting blood pressure.[1,3] The present findings show that the distortion of vascular homeostasis is a clinical outcome of moderate to severe menstrual pain. Cardiovascular changes, leading to silent myocardial infarction and ischemia, are spontaneous responses to acute pain,[33,34] where an inverse relationship has been identified between resting BP and acute pain[35]. In our study, the carbohydrate foods consumed over three consecutive menstrual cycles elevated the blood pressure of 34.7% non-dysmenorrhoeal participants above the 120/80 gold standard for young adults. All participants who experienced severe menstrual pain and ate carbohydrate meals over 3 consecutive cycles showed elevated blood pressure beyond the gold standard. Overall, carbohydrate consumption during menstrual flow increases blood pressure in both dysmenorrhoeal and non-dysmenorrhoeal young adults. This may reflect the effect of carbohydrates on blood pressure.[36] By contrast, vegetable foods normalised the 60% of participants whose blood pressure was elevated, due to severe menstrual pain. Modest vegetable consumption prevents excessive blood-pressure changes.[37] Thus, premenstrual vegetable consumption is recommended to stabilise blood pressure in severely dysmenorrhoeal young adults. The activities of vasoactive peptides also validate this recommendation. Clearly, the vascular system is equally compromised through menstrual pain. In addition, the positive correlation between premenstrual food and the activities of ANG-II and VCAM-II validates the argument that the type of food eaten immediately before menstruation affects the severity of menstrual pain. It is worth noting that the activities of the two peptides were unaffected in non-dysmenorrhoeal participants who ate carbohydrate foods prior to menstrual flow. This may reflect the outcome of a few non-dysmenorrhoeal participants, who became mildly to moderately dysmenorrhoeal after carbohydrate meals. Angiotensin-II is a vasoconstrictor, whose elevated

secretion increases blood pressure. VCAM-1 activities become compromised during vascular dysfunction. The mechanism behind the increased ANG-II and VCAM-1 in moderately and severely dysmenorrhoeal participants who ate carbohydrate foods prior to menstruation needs further investigation. By contrast, both spinach and okra are well-documented angiotensin-converting enzyme inhibitors,[38] possibly contributing to the mechanism behind the reduced activities of ANG-II in dysmenorrhoeal participants who ate vegetable meals. In other words, the synthesis of angiotensin II by the angiotensin-converting enzyme in dysmenorrhoeal participants who ate vegetable meals may have been suppressed by the bioactive constituents of okra and spinach. Spinach also suppresses vascular inflammation,[39] thereby modulating the release of VCAM-1 in free circulation. This suggests that, in addition to menstrual pain relief after consistent pre-menstrual consumption of vegetables, blood pressure and vascular health are positively modulated. While this represents an interesting outcome, future studies should use larger sample sizes and include more vegetables to draw stronger inferences.

Conclusion

Dysmenorrhoea can be categorised by circulating levels of contactin-1. Changes in blood pressure and vascular health are among the clinical outcomes of dysmenorrhoea, which reflects the type of food consumed prior to menstruation. Carbohydrate intake prior to menstrual flow exacerbates menstrual pain and elevates blood pressure in non-dysmenorrhoeal moderately and severely dysmenorrhoeal women. Proteinaceous foods lead to more pain after repeated premenstrual intake. By contrast, vegetables reduce menstrual pain in dysmenorrhoeal women, causing a larger percentage to experience no menstrual pain, stabilised blood pressure, and improved vascular health.

Recommendations

This study presents an interesting perspective on the non-pharmacological nutritional management of severe menstrual cramps. The consumption of vegetables should form a compulsory premenstrual dietary habit for severe dysmenorrhoeal girls, who should also avoid carbohydrates. Based on this study, researchers are advised to investigate the actual mechanism behind the pain-reduction associated with eating vegetables, as well as the issue of moderately dysmenorrhoeal women becoming severely dysmenorrhoeal after eating carbohydrates.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

The study protocol was approved by the Biochemistry Research and Ethics Committee, Imo State University, Owerri, Imo State, Nigeria, which issued an ethical approval number: IMSU/BCH/ETS/20190710, Dated 10th July 2019. All participants provided written consent to participate.

Authors' contributions

PUA conceived of the study. PUA and UCJ designed the study. PUA, UCJ, and JAA conducted the research, and provided research materials. PUA, UCJ, and JAA collected, organised, analysed, and interpreted the data. PUA wrote the initial and final drafts of the article, while UCJ provided logistic support. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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