Decompression Sickness in Women: A Possible Relationship with the Menstrual Cycle

VIVIENNE LEE, MARGUERITE ST. LEGER DOWSE, CHRISTOPHER EDGE, ALEX GUNBY, AND PHILIP BRYSON

LEE V, ST. LEGER DOWSE M, EDGE C, GUNBY A, BRYSON P. *Decompression sickness in women: a possible relationship with the menstrual cycle.* **Aviat Space Environ Med 2003; 74:1177–82.**

Background: Women are increasingly participating in recreational scuba diving and the professional roles of women are expanding in the fields of aviation, space, and diving. Evidence exists that there may be a relationship between altitude decompression sickness (DCS) and the menstrual cycle, although diving studies to support such findings are limited. The aim of the present study was to investigate the presence of any relationship between the development of DCS in female sports divers, the phase of the menstrual cycle, and the use of the oral contraceptive pill (OCP). ***Method:*** Personal, dive, symptom, and menstrual history details were collected by questionnaire from women treated with hyperbaric therapy for DCS in 23 treatment centers worldwide. ***Results:*** There were 150 records suitable for analysis. The phase in the menstrual cycle of the DCS incident was estimated. The DCS incidents were unevenly distributed throughout the cycle ($p = 0.001$) with the greatest percentage of incidents occurring in the first week of the menstrual cycle. The variation in incidence across the cycle appeared to be greatest for the non-OCP users ($p = 0.01$), and when age was taken into account there was a significant difference between the OCP and non-OCP users with respect to risk of DCS across the menstrual cycle ($p = 0.03$). ***Conclusion:*** These data suggest that the risk of DCS may be dependent on the phase of the menstrual cycle and that the distribution of risk differs between OCP and non-OCP users.

Keywords: women, scuba diving, decompression illness, menstruation.

INCREASING NUMBERS of women are participating in sports diving (British Sub Aqua Club and Professional Association of Diving Instructors. Unpublished data; 2001). Additionally, careers are opening up to women in commercial diving (UK Health and Safety Executive. Ralph Mavin. Personal communication; 2001) and, in many countries, military flying (4). A greater number of women than ever are, therefore, being exposed to the reduction in pressure that may place them at risk of decompression sickness (DCS). Several studies suggest that there may be a greater susceptibility to symptoms of DCS in women compared with men. However, the available evidence is inconclusive and conflicting. While some studies suggest a substantially greater risk associated with women (1–3,5), others suggest little or no difference in risk (7,9–11,18,19,21).

A small number of studies have investigated the effect of the menstrual cycle on the risk of DCS in women. Dunford and Hampson (7), Krause et al. (14), and Rudge (15) have indicated that the risk of DCS in women may be related to the phase of the menstrual cycle. In a study analyzing the development of symptoms of DCS in 81 women exposed to simulated altitude in a hypobaric chamber, Rudge (15) found a significant inverse linear correlation between the number of days since the start of the last menstrual period and the incidence of DCS. Krause et al. (14) also reported a correlation between menstrual day and DCS incidence in 62 females who developed DCS on exposure to a hypobaric environment, with the greatest probability of DCS developing on day two of the menstrual cycle. Dunford and Hampson (7) concluded that menses is a significant risk factor for hyperbaric chamber attendants but, interestingly, not for recreational divers in open water. However, this conclusion was based on the menstrual history from just 9 female hyperbaric chamber attendants and 24 female recreational divers with DCS. In one further study, while no effect of the menstrual cycle was demonstrated, it was observed that all five female subjects who experienced hypobaric DCS were in menses or the early phase of their menstrual cycle (5).

Furthermore, a small number of studies have attempted to identify the effect of the oral contraceptive pill (OCP) on the incidence of DCS in women. The available evidence provided by these studies, however, is not conclusive. One retrospective study, based on 29 women who had described symptoms but had not all required hyperbaric treatment, found that there was no difference in DCS between women taking the OCP and non-OCP users (1). In contrast, a study using data collected between 1989 and 1995 of 956 women concluded that OCP users are significantly more likely to experience DCS if they scuba dive while menstruating (6). This was compared with non-OCP users who, it was concluded, are not at greater risk while menstruating

From QinetiQ, Farnborough, Hampshire, UK (V. Lee), the Diving Diseases Research Centre (DDRC), Plymouth, UK (M. St. Leger Dowse, A. Gunby, P. Bryson), and The Nuffield Department of Anaesthetics, John Radcliffe Hospital, Headington, Oxford, UK (C. Edge).

This manuscript was received for review in April 2002. It was revised in March and June 2003. It was accepted for publication in June 2003.

Address reprint requests to: V. M. Lee, QinetiQ, Cody Technology Park, Room 1011, Building A50, Ively Road, Farnborough, Hampshire, GU14 0LX, United Kingdom; vmlee@qinetiq.com.

TABLE I. PERCENTAGE OF WOMEN REPORTING EACH SYMPTOM AND THE PERCENTAGE EACH REPORTING MODERATE OR SEVERE SYMPTOMS.

Questionnaire Symptom Category	% with Symptom	% Moderate or Severe
Skin itching/tingling	66	33
Upper limb or joint pain	61	53
Inappropriate fatigue or weakness	59	74
Dizziness or disorientation	46	66
Loss of sensation or numbness	41	45
Lower limb or joint pain	38	40
Problems with thinking, memory or performance	29	52
Visual disturbances	23	66
Other	23	79
Chest pain or breathlessness	20	67
Skin rash	11	23
Difficulty in speaking	9	69
Partial paralysis	3	75

(6). Most recently, Webb et al. (19) reported that in the hypobaric environment, women using hormonal contraceptives were more likely to develop DCS than those not using hormonal contraception. They found that while there was no difference between the two groups during the first and second weeks of the menstrual cycle, in the last 2 wk the use of hormonal contraceptives appeared to double the risk of DCS.

The limited evidence for a relationship between DCS and the menstrual cycle comes mainly from the hypobaric environment. Therefore, the aim of the present study was to investigate the relationship between the development of DCS in sports divers, the phase in the menstrual cycle, and the use of the OCP, together with the impact of any such relationship.

METHODS

A questionnaire was compiled, with the Center for Human Science's Local Ethics Committee approval, to gather personal, dive, symptom, and menstrual history details from female sports divers who presented at hyperbaric treatment centers with DCS. Hyperbaric treatment centers worldwide were contacted, and questionnaires distributed by the Diving Diseases Research Center (DDRC) to those treatment centers willing to participate in the study. Women diagnosed by the hyperbaric center's physician and treated for DCS with hyperbaric therapy were asked by the treatment center to complete and return the questionnaire prior to discharge. The questionnaire asked subjects to record the details, including date and maximum depth, of up to 12 dives prior to presentation of symptoms and indicate which of the symptoms in **Table I** they had experienced. Respondents indicated whether the severity of each symptom was slight (barely noticeable), mild (noticeable but did not interfere with normal activities), moderate (difficult to concentrate on normal activities), or severe (disrupted ability to perform normal activities). The time between the dive and onset of the symptoms was also recorded (while diving, within 30 min of surfacing, 30 min to 1 h after surfacing, 1 h after surfacing). Additionally, treatment details, usual length of the menstrual cycle, date of the first day of the last menstrual period prior to the incident, and OCP usage were recorded. Personal details including age, height, weight, smoking habits, and alcohol consumption were also gathered. Questionnaires were in confidence once completed by respondents.

Completed questionnaires were returned to DDRC by participating hyperbaric chambers between April 1997 and March 2001. In addition, treatment records of women presenting at the DDRC for diving DCS between 1986 and 1997 were scrutinized and records that contained all the necessary information were included with the questionnaire data. When the dive prior to the signs and symptoms of DCS was recorded as over 50 m or below 10 m, further details were obtained from the treatment chamber to verify the depth and treatment. The data were transferred to a database by trained operators, and all record and data entry quality assessed by additional technicians.

Data Analysis

The first day of the menstrual cycle, i.e., the first day of bleeding, was recorded as day zero. The number of days between the incident that resulted in diagnosis of DCS by the treatment center physician and subsequent hyperbaric therapy, and the first day of the last menstrual period was calculated for all respondents. In order to compare the phase in which the DCS incident occurred in women with differing cycle lengths, the phases of the menstrual cycle were expressed as a number between 0 and 27, representing a 'standard cycle length in days.' The estimate of the phase in which the DCS incident occurred was calculated using the following formula:

$$\text{Phase} = \frac{28 \times (D + 0.5)}{L}$$

where D is number of days between the incident and the first day of the last menstrual period, and L is the recorded cycle length. A continuity correction of 0.5 has been applied.

A logistic regression analysis was carried out to establish whether the risk of DCS was related to the phase of the menstrual cycle. In addition, the effects of OCP use, age, BMI, dive depth, and smoking were investigated by including these variables as covariates in the regression model. Selection of the significant covariates was made using the stepwise-backward method. Where appropriate, data were checked to ensure the distributional assumptions for tests and analytical methods were met.

The Chi-squared test was used to compare distributions of the data. In addition, the Kolmogorov-Smirnov test was applied as it makes no distributional assumptions and makes use of the ungrouped data (using instead the cumulative distribution function).

RESULTS

A total of 240 questionnaires were returned from 23 hyperbaric treatment centers (7 from the USA, 2 from the Caribbean, 5 from Australasia, 1 from the Red Sea

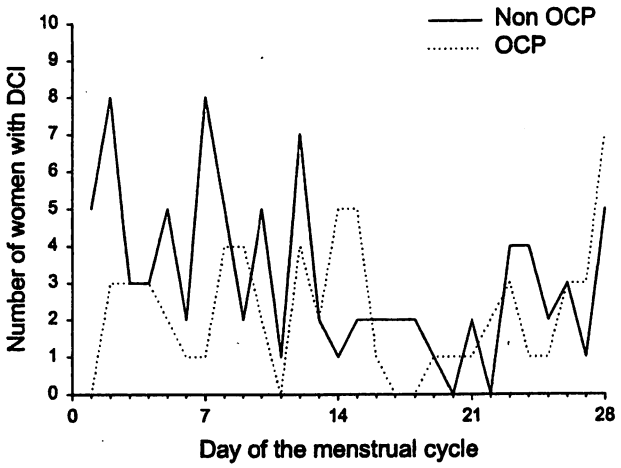

Fig. 1. Number of women (non-OCP users & OCP users) developing symptoms each day of the menstrual cycle.

region, and 8 from Europe). In addition, 28 retrospective records from DDRC hyperbaric DCS treatments were analyzed. Records were discarded if the questions were not completed that recorded the date of the dive resulting in DCS, usual length of menstrual cycle, date of the start of the last menstrual period, and use of the oral contraceptive pill. The only exception was those women on the OCP who had failed to state the length of their usual cycle; for these records a cycle length of 28 d was assumed, thereby allowing these records to be included. A total of 150 records were suitable for analysis.

All data are reported as: range (mean ± SE). The age of the subjects at the time of the incident was 16–50 yr (29 ± 0.6), and the estimated BMI was 18–34 (23 ± 0.2). The cycle length of the non-OCP women was 23–42 d (29 ± 0.3) while OCP users reported cycle lengths of 28 d. The depth of the dive prior to presentation of DCS was 2–174 m (23 ± 1.7). Out of the 150 respondents, 5 reported maximum dive depths in excess of 50 m, and 1 reported a dive depth in excess of 100 m conducted on Trimix. All dives deeper than 50 m were verified by the treating chamber. Confirmation of the requirement for hyperbaric therapy was sought from the treating chamber when dives were less then 10 m. Although women were asked to give details of up to 11 dives prior to the incident, the information provided was not complete enough to allow for any data analysis regarding the influence of cumulative dives. Of the respondents, 25% smoked (maximum 30 cigarettes/d) and 61% reported that they consumed alcohol (maximum 6 units/d) on a regular basis. The distributions of age, estimated BMI, and smoking status of subjects were compared with the distributions observed in a population of 1,050 female sports divers (16) using both Chi-squared goodness-of-fit tests and two-sample Kolmogorov-Smirnov tests. In addition, the depths of dives prior to reporting symptoms were compared with data from 37,555 dives completed by women during the period 1996–1999 (St. Leger Dowse. Unpublished data; 2000). There were no significant differences between the distribution of age, BMI, smoking status, or dive depth between the women in this study and the female UK diving population as reported by the St. Leger Dowse study (16; and St. Leger Dowse. Unpublished data; 2000).

The number of OCP and non-OCP respondents developing symptoms by phase of the menstrual cycle is shown in **Fig. 1**. The number of respondents developing symptoms during each of the 4 wk of the standardized menstrual cycle was calculated. **Fig. 2** shows the percentage of all respondents developing DCS during each of the 4 wk of the standardized menstrual cycle. The greatest percentage of DCS symptoms occurred during the first week of the menstrual cycle, the incidence of DCS then appears to fall with the greatest reduction being in week 3, the incidence then rises again in week 4. A Chi-squared test for randomness across the 4 wk of the cycle and a one-sample Kolmogorov-Smirnov test for uniformity of the distribution of DCS both suggest that the distribution of all DCS incidents is not uniform throughout the cycle ($p = 0.015$ and $p = 0.01$ respectively).

OCP users made up 42% and non-OCP users 58% of the 150 respondents. Statistical analysis indicates a non-uniform distribution of DCS cases across the menstrual cycle in the non-OCP group (Chi-squared test for randomness $p = 0.01$ and one-sample Kolmogorov-Smirnov $p = 0.01$). In contrast, no significant difference could be found in the distribution of DCS across the cycle for those women using the OCP (**Fig. 3**), indicating that there may be an effect of OCP usage on the risk of DCS at different phases of the menstrual cycle.

Further analysis was conducted to establish whether any of the parameters recorded affect the phase at which DCS occurs. A logistic regression of phase against OCP usage, age, BMI, smoking, and dive depth was performed, revealing that BMI, smoking, and dive depth had no significant effect. However, the combined effect of OCP usage and age were found to be significant ($p = 0.025$) and neither covariate could be removed from the model without reducing the fit significantly. When age was taken into account, there was a significant difference between the OCP and non-OCP users with respect to risk of DCS across the menstrual cycle ($p = 0.03$).

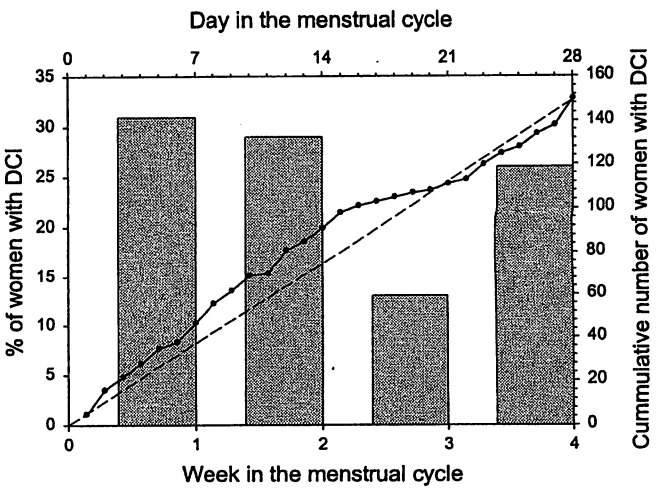

Fig. 2. Percentage of women developing symptoms of DCS during each week of the menstrual cycle (bar chart), together with cumulative frequency.

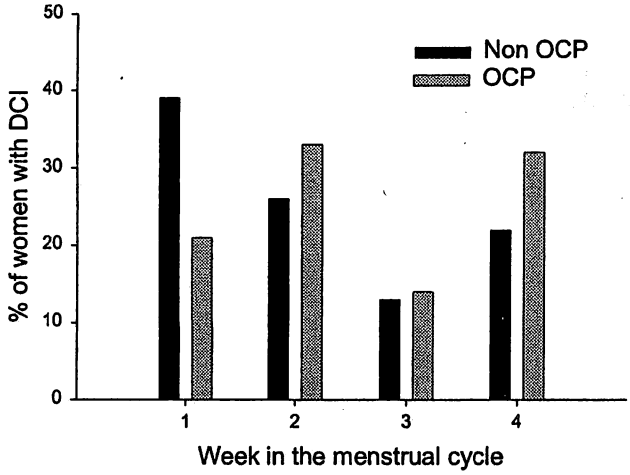

Fig. 3. Percentage of women, both non-OCP users and OCP users, with DCS symptoms during the 4 wk of the menstrual cycle.

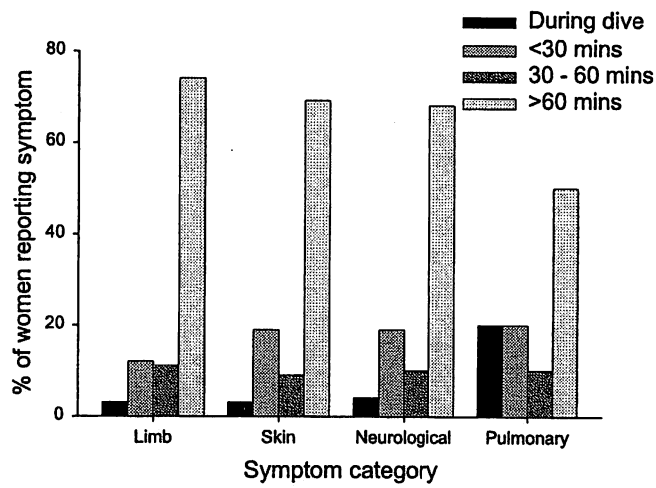

Fig. 4. Percentage of women reporting onset of limb, skin, pulmonary, or neurological symptoms during the dive, within 30 min, between 30 and 60 min, and after 1 h of surfacing.

Table I shows the percentage of women reporting each symptom, together with the percentage of those with moderate or severe symptoms. This table reflects the total of 643 symptoms reported by the 150 women. Of the symptoms listed in Table I, 90% of the women reported two or more, while 60% reported four or more. There were 2 women who reported developing at least 10 of the 13 symptoms listed. Limb symptoms were the most frequently reported, with 69% of women reporting symptoms of upper or lower limb pain or both. Among all the symptoms, 29% began to develop within 1 h of surfacing, 65% developed 1 h after surfacing, and only 6% manifested during the dive. Details of times to symptom onset were not collected beyond 1 h of surfacing; however, comparison of the date of incident with the date of treatment indicates that 77% of respondents were treated within 2 d. It is of interest that in an additional 6% of respondents, it was apparent that treatment was delayed beyond 2 d as they had continued to dive after the incident.

The 643 symptoms reported were then categorized into either limb (upper and/or lower limb pain), skin (rash and itch), pulmonary (chest pain and breathlessness), or neurological (all remaining symptoms). **Table II** shows the percentage of subjects reporting each symptom type during each week of the standardized cycle. In addition, the time to onset for each symptom category is shown in **Fig. 4**. Kolmogorov-Smirnov tests were used to compare the cumulative distributions of each of the symptoms against the distribution of DCS across the menstrual cycle (Chi-squared tests were not used as the expected values of the binned data were often too small). The distributions of the symptom groups across the menstrual cycle are not significantly different from the spread of DCS (minimum $p > 0.23$). When the data are further examined by pill usage, this pattern is repeated; no significant differences between the distribution of symptoms and the distribution of DCS were found for any of the symptom groups by pill usage (minimum $p > 0.14$).

TABLE II. PERCENTAGE OF WOMEN REPORTING A SYMPTOM WITHIN EACH CATEGORY DURING THE 4 WK OF THE CYCLE.

	Week of the Menstrual Cycle			
	1	2	3	4
Limb pain (%)	32	34	13	21
Skin (%)	32	32	14	22
Pulmonary (%)	30	23	23	23
Neurological (%)	30	29	16	25

DISCUSSION

This study investigated the hypothesis that the exposure to the risk of DCS is uniform throughout the menstrual cycle; thus, 25% of all incidents would be expected in each week of the cycle. The results, however, suggest an effect of the phase of the menstrual cycle on the incidence of reported DCS in female sports divers. The overall reported incidence is highest during the first half of the cycle, then falling markedly during the third week, and rising again for the last week of the cycle. Previous research has shown that 7% of female sports divers refrain from diving while menstruating, and 12% of those diving reported undertaking more conservative dives while menstruating (16). This suggests that if equal numbers of women were diving during each week of the standardized menstrual cycle, the incidence of DCS would be even greater in the first week than revealed in our results.

Our data confirm results from previous hypobaric studies that concluded the greatest risk of DCS appears to be at the beginning of the menstrual cycle, particularly for women taking the OCP (5,14,15). It also confirms Rudge's (15) results that the incidence of DCS appears to drop as the menstrual cycle proceeds during the first 3 wk. In addition, our findings confirmed those of Rudge, who concluded that the effect of the menstrual cycle on the incidence of DCS was not symptom specific. In contrast with Rudge, however, who concluded that the incidence of hypobaric DCS continues to fall throughout the menstrual cycle, our study found that the incidence rises again at the very end of the

TABLE III. NUMBER OF CASES OF DCS RECORDED DURING THE 4 WK OF THE MENSTRUAL CYCLE IN CURRENT STUDY AND RUDGE (15).

	Weeks of the Menstrual Cycle				
	1	2	3	4	Total
Current study	47	43	21	39	150
Rudge	32	20	18	8	78

menstrual cycle immediately prior to menstruation. **Table III** illustrates this differing distribution across the 4 wk of the menstrual cycle. When Rudge's data are examined in more detail, it can be seen that only 27% are OCP users compared with 42% in our study. This results in a relatively small sample size for his OCP group. In addition, Rudge's results are based on women under the age of 40 compared with this current study which included women up to the age of 50. When our data are filtered to exclude women over the age of 39, and the non-OCP groups from both studies are then compared, the distribution of DCS in the two studies for these women show a closer agreement.

As far as we are aware, this study provides the only evidence to suggest an increase in DCS incidence immediately prior to menstruation. However, there are a number of differences between this and previous studies which may influence the distribution of DCS incidence (e.g., sample size, which is considerably greater in this study). In addition, the length of the usual cycle of each woman was known in our study, allowing the phase in the menstrual cycle of DCS incidents to be estimated for 150 respondents. It should also be remembered that in this study, the sample population was taken from the general recreational diving population compared with previous hypobaric studies where subjects could be assumed to have met defined USAF physical standards (14,15). Lastly, the incidence of DCS resulting from the hyperbaric environment is being compared with that resulting from a hypobaric environment.

The variation in distribution across the menstrual cycle appears to be greatest for the non-OCP users in this study. When the distribution of DCS in OCP and non-OCP users are first compared, there is no significant difference, which supports Bangasser's conclusion (1). However, our data suggest that there is a significant difference in the risk of DCS between OCP and non-OCP users when age is taken into account. Indeed, when age is taken into account, there is an indication of a correlation between pill usage and the phase in the cycle when DCS occurs. The effect of pill usage appears to shift the occurrence of the DCS to later in the cycle compared with distribution of DCS in non-OCP users (Fig. 1). This finding is similar to that reported by Webb et al. (19). These results are contrary, however, to Doyle et al. (6), who concluded that while OCP users were significantly more likely to develop symptoms while menstruating, non-OCP users were not. The reason for the difference in the two studies is unclear, although the results of this study are based on more detailed menstrual history data than that of the retrospective study of Doyle et al. Comparison of data from women taking the OCP, however, may be difficult as different OCPs have differing hormonal compositions and doses.

The symptoms reported by respondents in this study were consistent with previous studies (8,17). The time to onset of symptoms, relative to the dive, did not differ between the 13 symptom types or the 4 symptom categories. The cases represented in the study were all reviewed by a hyperbaric physician who considered the symptom, or combination of symptoms, serious enough to require hyperbaric therapy. Treatment for DCS was verified by the hyperbaric treatment center when dives were less than 10 m in depth. While hyperbaric therapy instigated by a hyperbaric physician may not be definitive evidence of DCS, we considered that it gives the most reliable method of providing a diagnosis for a questionnaire study such as this.

In populations exposed to reduced ambient pressure (ascent to altitude or ascent from depth), the known and estimated incidence of DCS is relatively low (12,13,15,20). The largest population exposed to such a changing environment is that of sports divers, who are probably one of the best sources of data on DCS in the absence of a controlled laboratory study. Unfortunately, the majority of data collected by hyperbaric treatment centers in the past have not provided enough information to allow correlation of the development of DCS symptoms with the day in the menstrual cycle. Additionally, experience from this study has shown that when women are requested to provide menstrual and dive data in enough detail to allow study of any relationship between DCS and the menstrual cycle, they are not always able to do so. Therefore, our understanding of the relationship between the menstrual cycle and the incidence of DCS would be furthered by more detailed and uniform data collection by hyperbaric treatment centers worldwide.

The mechanism for the differing distribution of DCS across the menstrual cycle is not as yet understood. However, it does not seem unreasonable to assume that the changes in hormone levels throughout the menstrual cycle may influence this distribution. This would be supported by our results that show that the variation is greatest in the non-OCP group. Furthermore, it cannot be established whether the changes in hormone levels during the menstrual cycle protect against DCS during the third week, or exacerbate the risk during the first week. It is intended that data collection will continue using an extended questionnaire in order to provide a greater understanding in this area.

ACKNOWLEDGMENTS

The authors would like to thank personnel at all participating chambers, without whose efforts this study would not have been possible.

REFERENCES

1. Bangasser S. Medical profile of the woman scuba diver. In: National Association of Underwater Instructors. Proceedings of the 10th International Conference on Underwater Education, 1978 November 9–12; Anaheim, CA. Colton, CA: NAUI; 1978: 31–40.
2. Bassett BE. Decompression sickness in female students exposed to

altitude during physiologic training. In: Pre-prints of the Aerospace Medical Association Annual Scientific Meeting. Alexandria, VA: Aerospace Medical Association; 1973:261–2.
3. Bassett BE. Twelve year survey of the susceptibility of women to altitude decompression sickness. In: Pre-prints of the Aerospace Medical Association Annual Scientific Meeting. Alexandria, VA: Aerospace Medical Association; 1980:12–3.
4. Brooks CJ. A brief introduction to the history of women in aviation. In: Conference proceedings of the AGARD Symposium on Recruiting, Selection, Training, and Military Operations of Female Aircrew. Neuilly-sur-Seine, France: NATO; 1990; AGARD-CP-49–1:I.1-I:3.
5. Dixon GA, Krutz RW, Fischer MS. Decompression sickness and bubble formation in females exposed to a simulated 7.8 psia suit environment. Aviat Space Environ Med 1988; 59:1146–9.
6. Doyle K, Baek PS, De Long ER, et al. Menstruation as a risk factor for decompression illness (DCI) in female scuba divers taking oral contraceptives (OC). Undersea Hyper Med 1997; 24(Suppl):33.
7. Dunford RG, Hampson NB. Gender-related risk of decompression sickness in hyperbaric chamber inside attendants. A case control study. Undersea Biomed Res 1992; 19(Suppl 41):37.
8. Dutka AJ, Francis TJ. Pathophysiology of decompression sickness. In: Bove AA, ed. Bove and Davis' diving medicine. 3rd ed. Philadelphia: Saunders; 1997:159–75.
9. Eckenhoff RG, Olstad CS. Gender effect on venous bubble formation after decompression from prolonged 16 fswg exposures. Undersea Biomed Res 1990; 17(Suppl 104):77–8.
10. Fife CE, Pollard GW, Mebane GY, et al. A data base of open water, compressed air, multi-day repetitive dives to depths between 100 and 190 fsw. In: Lang MA, Vann RD eds. Repetitive diving workshop. Proceedings of the American Academy of Underwater Sciences;1991 March 18–19; Durham, CA. Mesa, CA: AAUS; 1991; AAUSDSP-RDW-02-92:45–54.
11. Fife W. Women in diving: second study. In: Dennis GD, ed. Diving physiology and technology. Proceedings of the 10th Meeting of the United States - Japan Cooperative Program in Natural Resources (UJNR); 1989 June 4–7; Kauai, Hawaii. Washington, DC: U.S. Department of Commerce; 1989:19–38.
12. Harding RM. Experience outside North America. In: Pilmanis AA, ed. The proceedings of the 1990 hypobaric decompression sickness workshop; 1990 Oct 16–18; Brooks AFB, Armstrong Laboratory, TX. 1992; AL-SR-1992-0005:467–71.
13. Kemper G. USAF aircraft operations: decompression sickness (DCS) mishaps. In: Pilmanis AA, ed. The proceedings of the 1990 hypobaric decompression sickness workshop; 1990 Oct 16–18; Brooks AFB, Armstrong Laboratory, TX. 1992; AL-SR-1992-0005:373–8.
14. Krause KM, Pilmanis AA, Webb JT. The effect of menstrual day on decompression sickness (DCS) incidence in female research subjects. Aviat Space Environ Med 1998; 69:199.
15. Rudge FW. Relationship of menstrual history to altitude chamber decompression sickness. Aviat Space Environ Med 1990; 61: 657–9.
16. St Leger Dowse M, Bryson P, Gunby A, Fife W. Comparative data from 2250 male and female sport divers: diving patterns and decompression sickness. Aviat Space Environ Med 2002; 73: 743–9.
17. Vann RD, Uguccioni D, eds. Report on decompression illness, and diving fatalities. DAN annual review of recreational scuba diving injuries and deaths based on 1998 data. Durham, NC: Center for Hyperbaric Medicine and Environmental Physiology, Duke University Medical Center; 2000.
18. Waligora JM, Horrigan D, Conkin J, Gilbert JH. Incidence of symptoms and venous gas bubbles in male and female subjects after decompression. In: Pre-prints of the Aerospace Medical Association Annual Scientific Meeting. Alexandria, VA: Aerospace Medical Association; 1986:511.
19. Webb JT, Kannan N, Pilmanis AA. Gender not a factor for altitude decompression sickness risk. Aviat Space Environ Med 2003; 74:2–10.
20. Wilmshurst P. Analysis of decompression accidents in amateur divers. Prog Underwater Sci 1990; 15:31–7.
21. Zwingelberg KM, Knight MA, Biles JB. Decompression sickness in women divers. Undersea Biomed Res 1987; 14:311–7.