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Problems associated with scuba diving are not evenly distributed across a menstrual cycle

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Summary
The problems encountered during scuba diving may be a contributing factor in an episode of decompression illness (DCI). Evidence exists that there may be a relationship between the position in the menstrual cycle and the occurrence of DCI. We examined, by prospective observation in female recreational scuba divers, any interaction between reported problems during diving (RPDD) and the position in the menstrual cycle. A total of 533 women, aged between 14 and 57 years, returned diaries for >6 months, with 61% returning diaries for 3 consecutive years. A total of 34,625 dives were reported within 11,461 menstrual cycles between 21 and 40 days in length, with 65% of women reporting at least one RPDD. Logistic regression showed a significant non-linear relationship between the position in the menstrual cycle and RPDD ($p = 0.004$). RPDD were not evenly distributed over the menstrual cycle; the rate per 1,000 dives varied from 39.2 at start of the cycle to 19.7 during week 3, and 31.9 in week 4. We concluded these field data suggest a possible correlation between the incidence of RPDD and the position in which they occurred in the menstrual cycle.

Introduction

Women are participating in the activity of scuba diving for both recreational and commercial purposes. However, the inquiring diver or diving instructor has little access to information with regard to relationships between scuba diving, the menstrual cycle and a woman's ability to dive safely (Willson et al. 1983; Taylor 1997). Some studies in non-diving populations have observed changes in cognitive, psychological and physiological functions over the menstrual cycle (Hausmann et al. 2000; Mumenthaler et al. 2001; Maki et al. 2002). Most female specific diving data in a general context are drawn from retrospective studies, abstracts, military records and diving incident reports (Bangasser 1978; Bassett 1980; Zwingelberg 1987; Fife 1989; Lee et al. 1998; Vann and Uguccioni 2000; St Leger Dowse et al. 2002, 2003). Overviews exist (Taylor 1997), with ongoing debate and controversy over anecdotal observations. No attempt has been made, to date, to observe reported problems during diving and any relationship with the menstrual cycle other than in decompression illness (DCI) studies.

This study sought to provide an insight into the everyday diving patterns of a large group of women over a period of up to 3 years, observing any interaction between reported problems during diving and the menstrual cycle.

Methods

Female recreational scuba divers voluntarily kept menstrual and diving 'diaries' for up to 3 consecutive years. Participation was entirely voluntary and no incentive was offered to participate. Each woman was free to terminate her participation in the project at any time.

Information gathered included general health, gynaecological health, contraception and oral contraceptive pill (OCP) usage, diving experience to date and general diving practices. Date-defined diaries recorded every day of bleeding, type of bleed (spotting, low, medium and heavy), and basic dive profiles (maximum depth, total dive time and decompression stop required). Women completed the menstrual detail irrespective of whether they were diving during that particular month/cycle, and completed diving details irrespective of whether they were menstruating. Respondents documented reported problems during diving (RPDD) choosing from a list of 11 RPDD fixed options: alcohol, illness, drugs, pushing tables/computer, visibility, buoyancy, cold, equipment, out of air, symptoms and 'none of these'. The last category ('none of these') allowing for any problems not listed to be recorded.

At no time did this study seek to observe the incidence of physician diagnosed and treated DCI over the menstrual cycle. Diaries were returned every 6 months. The women were not aware of the specific aims of the project. The questionnaires and diaries were compiled in conjunction with a female psychologist who was an experienced diver.

Statistical analysis

The first day of the menstrual cycle (the first day of bleeding) was recorded as day 1. The number of days

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between the first day of the last menstrual period (LMP) and each recorded dive and RPDD was known for all respondents for every menstrual cycle. A total of 21% of the menstrual cycles were <21 days or >40 days and therefore considered outside the normal parameters for inclusion and were excluded from analysis (Treloar et al. 1967; Cooper et al. 1996; Guyton and Hall 1997). To enable inclusion of all the remaining menstrual cycles, the observed number of days from LMP to RPDD was transformed into the relative position (the normalised day) in a normalised cycle with length 28 days (Sibley et al. 1999; Lee et al. 2003; Ross et al. 2003). The normalised day in which each RPDD occurred was calculated using the following formula: normalised day $=$ $28 \times$ D/L, where D is number of days between the RPDD and the first day of the LMP, L is the recorded actual length of the cycle in which the RPDD occurred. The normalised day of the menstrual cycle is therefore a number between 1 and 28. Normalised day does not refer to the hormone status of the menstrual cycle. The data were examined for any variation in the occurrence of RPDD over the normalised day in the menstrual cycle. In addition to being included in the overall analysis, data from cycles of exactly 28 days from both OCP and non-OCP users were separately analysed.

The distribution of dives across the menstrual cycle was analysed using Kolmogorov-Smirnov tests. The normalising transformation was used to give the normalised day in the cycle of all dives during every menstrual cycle. The rate of occurrence of RPDD relative to the number of dives performed, broken down by normalised day in the cycle, was also observed. The analysis used the variable 'did the respondent report an RPDD on a particular dive?' as the binary response. The explanatory variables included in the model were normalised day, squared normalised day and OCP usage during that dive. Logistic regression was used to analyse the relationship between the rate of RPDD and normalised day of the menstrual cycle. Data were checked to ensure the distributional assumptions for tests and analytical methods were fulfilled.

Results

A total of 533 menstruating women divers returned dive and menstrual diaries for $\geq$6 months; 325 (61%) for 3 consecutive years. Age range at the start of the study was verified as 14–57 years (mean 34), and body mass index (BMI) ranged from 15.66 to 36.34 (mean 24). Some 90% (482/533) of women stated they menstruated regularly; 29% (156/533) were OCP users and 71% (377/533) used either no birth control or other methods of contraception (non-OCP users). A total of 95% (508/533) of women continued to dive during the menses, with 8% (41/508) stating dive profiles were more 'conservative' at this time.

Reported problems during diving (RPDD) during the study

From the 533 women who were menstruating, 65% (346/533) reported RPDD. A total of 34,625 dives from 21,165 dive days were reported within 11,461 menstrual cycles suitable for analysis, with diving taking place in 49% (5,596/11,461) of the menstrual cycles. These data were analysed as two separate groups; OCP and non-OCP users.

The spread of dives across the menstrual cycle was not significantly higher in any part of the normalised cycle (Figure 1).

The observed overall RPDD rate was 28.3 per 1,000 dives, but RPDD were not evenly distributed over the menstrual cycle and varied from 39.2 at the start of the cycle, to 19.7 during week 3, and 31.9 at the end of week 4. Logistic regression analysis shows that there was a significant, but non-linear, relationship between the normalised day of the menstrual cycle and rate of RPDD ($p = 0.004$). The relationship between OCP usage and non-OCP usage in this first analysis was not significant ($p = 0.098$) (Figure 2).

Similar results were seen when data analysis of both OCP and non-OCP groups was limited to dives that occurred during menstrual cycles of only 28 days, resulting in a significant, non-linear relationship between day and rate of RPDD ($p = 0.041$) but in this set of data the relationship with OCP usage was also significant ($p = 0.023$). The observed and estimated rates of RPDD per dive are shown in Figure 3 for this second restricted data set analysis.

Discussion

Our field data showed RPDDs were not evenly distributed over the menstrual cycle in this study population, despite

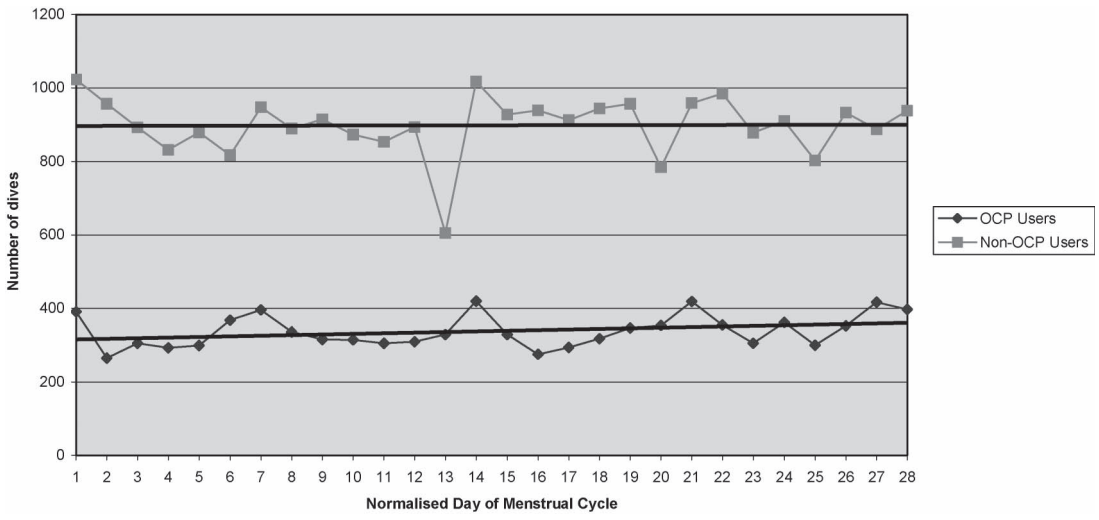

Figure 1. Distribution of dives across normalised menstrual cycles. OCP, oral contraceptive pill.

diving taking place consistently over the cycle. The trends demonstrated in this study are similar to two separate studies showing a relationship with the menstrual cycle and DCI (Rudge 1990; Lee et al. 2003).

The strength of this study is in the relatively large group of women observed over a 3-year period, resulting in, to our knowledge, the most comprehensive collection of female specific recreational diving field data ever gathered. The length of every menstrual cycle for each individual was known for a minimum of 6 months up to the maximum of 3 consecutive years, with our analysis enabling all menstrual cycle lengths within the range 21–40 to be included. Social trends, age distributions, health issues, OCP use and other methods of contraception were consistent with data from diving studies, and with the national non-diving population within the timeframe of the study (Dawe and Meltzer 2001; St Leger Dowse et al. 2003). The women did not change their diving habits as a result of this study (St Leger Dowse et al. 2004), as evidenced by the style of diving recorded and the even distribution of diving over the time of the study. The associations with RPDD and the position in the menstrual cycle in our study followed similar trends to that of two DCI studies (Rudge 1990; Lee et al. 2003). The trends

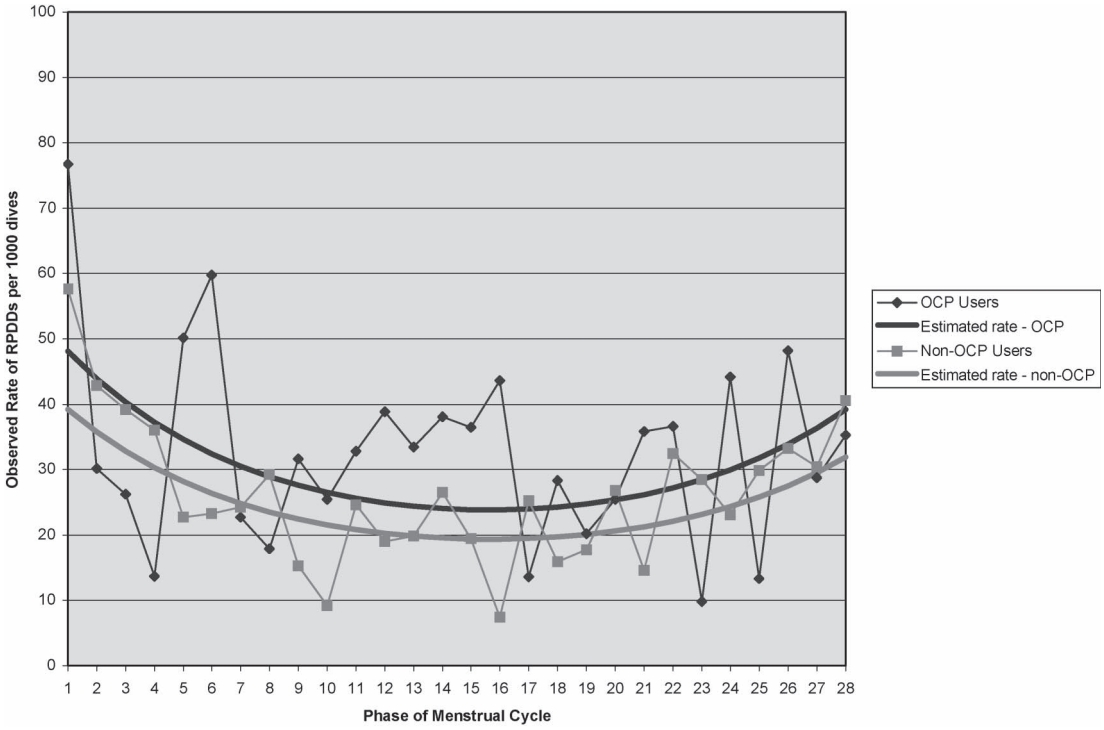

Figure 2. Rates of reported problems during diving (RPDDs) per 1,000 dives across normalised menstrual cycles. OCP, oral contraceptive pill.

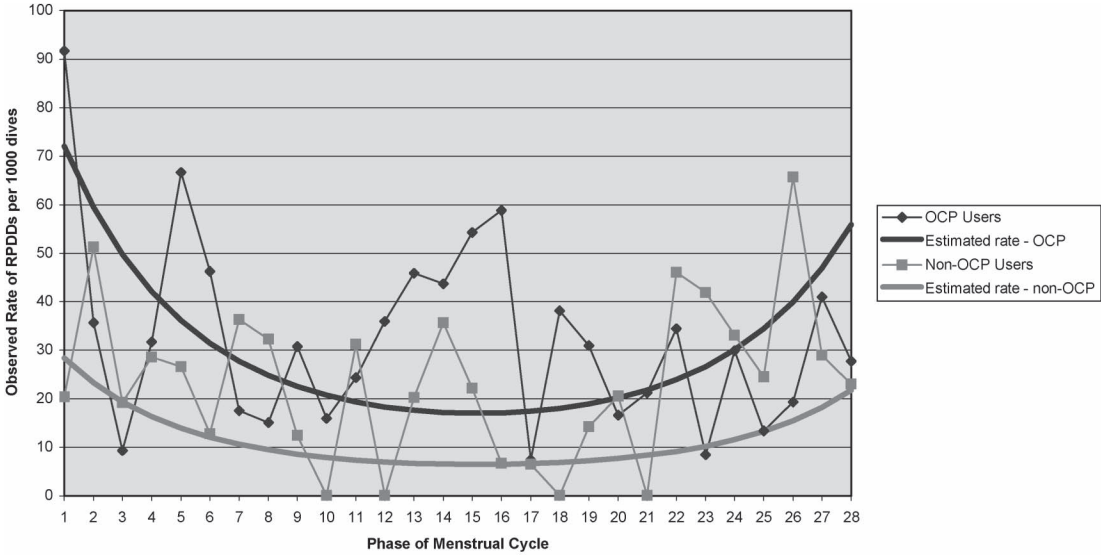

Figure 3. Rates of reported problems during diving (RPDDs) per 1,000 dives across menstrual cycles of exactly 28 days. OCP, oral contraceptive pill.

seen in the group (OCP and non-OCP) with menstrual cycles of 28 days only were similar to the larger normalised group with menstrual cycles of 21–40 days in length.

The weakness of this field study was the reliance on self-reporting women, thus the data may suffer from bias. Due to the physics of the sport a non-diving control group was considered inappropriate. An additional 37 women who took part in the study were postmenopausal or were not menstruating, reflecting the insufficient numbers of post-menopausal and/or non-menstruating women in the sport of scuba diving *per se*, or for a control group. These 37 women reported 3,408 dives, with 62% (23/37) reporting some form of RPDD from 2% (81/3,489) of the dives. This compares with the study group of 533 women, where 65% reported an RPDD from 3% of their recorded dives. Comparisons with data concerning problems encountered during diving in the general sport diving population are not possible due to the absence of such records. The British Sub Aqua Club (BSAC) annual incident report is the most comprehensive in the UK but deals only with significant incidents formally reported (National Diving Council [NDC] Diving Incidents Report 1999). Additionally, there are no reliable data indicating the number of recreational scuba dives taking place in the UK annually, although it has been estimated by the principal training agencies in the UK that there may be up to two million dives per year taking place (Diving Incidents Information 2004). There may be variability in how individual women interpret the extent of an RPDD. This poses the question of whether trends seen in individual categories are due to the effects of the menstrual cycle (Table I). If so, they could be described as errors of judgement and/or procedural error. Conversely they could be classified as external and/or physical influences that may have no correlation with the effects of the menstrual cycle. However, as diving took place evenly over the menstrual cycle in this study, problems with equipment would be expected to be reported evenly and also to be a rare occurrence given the reliability of modern technology. But there were many more occurrences of problems with equipment immediately before the onset of bleeding than would be expected, suggesting that some of these reports may be due to errors of judgement or procedural error.

Comparison with other studies

There are no published studies observing the effect of the menstrual cycle and reported problems during diving. Problems encountered during diving (Table I), however, are often part of an underlying and contributory factor in the incidence of DCI. Although this study was not designed to observe the occurrence of treated DCI *per se*, it is appropriate to compare our work with the limited altitude and diving studies. Table II shows studies that demonstrate the occurrence of medically confirmed DCI associated with the menstrual cycle (Dixon et al. 1988;

Table I. Fixed option reported problems during diving

	Days 1–7	Days 8–14	Days 15–21	Days 22–28	Totals
Equipment: failure and/or problem	39	37	26	60	162
Cold: felt cold during dive	58	30	31	36	155
Buoyancy: could not control	43	29	27	38	137
Symptoms: self reported of possible DCI	34	23	17	19	93
Illness: feeling unwell	24	14	15	20	73
Visibility: could not cope with lack of visibility	20	16	11	9	56
Out of air	5	7	5	4	21
Pushing tables/computers: risk taking	4	2	1	6	13
Alcohol: results of consuming alcohol	1	2	1	3	7
Drugs	0	0	0	0	0
None of these	93	38	49	82	262
Totals	321	198	183	277	979

Table II. Diving and altitude studies, DCI* and the menstrual cycle

Menstrual cycle and DCS studies (see refs)	Conclusions
Dixon et al. 1988	All 5/30 female subjects with hypobaric DCS were in menses or early phase of cycle
Rudge 1990	Significant inverse linear correlation between number of days since start of LMP and DCS incident, highest risk at the beginning of a 28-day cycle; 81 retrospective records studied
Dunford and Hampson 1992	Menses was a significant risk factor for inside chamber attendants, but not for divers in open water. This study was based on small numbers ($n = 9$)
Krause et al. 1998	Correlation between menstrual day and DCS: greatest probability being on day 2 of bleed; 62 retrospective records
Lee et al. 2003	Suggested the risk of DCS may be dependent on the phase of the menstrual cycle with greatest risk of DCS, in the non-OCP group, being in the 1st week of a 28-day cycle, the lowest risk being in week 3; 150 prospective records

*DCI encompasses the two conditions decompression sickness (DCS) and arterial gas embolism (AGE) following pulmonary barotrauma.

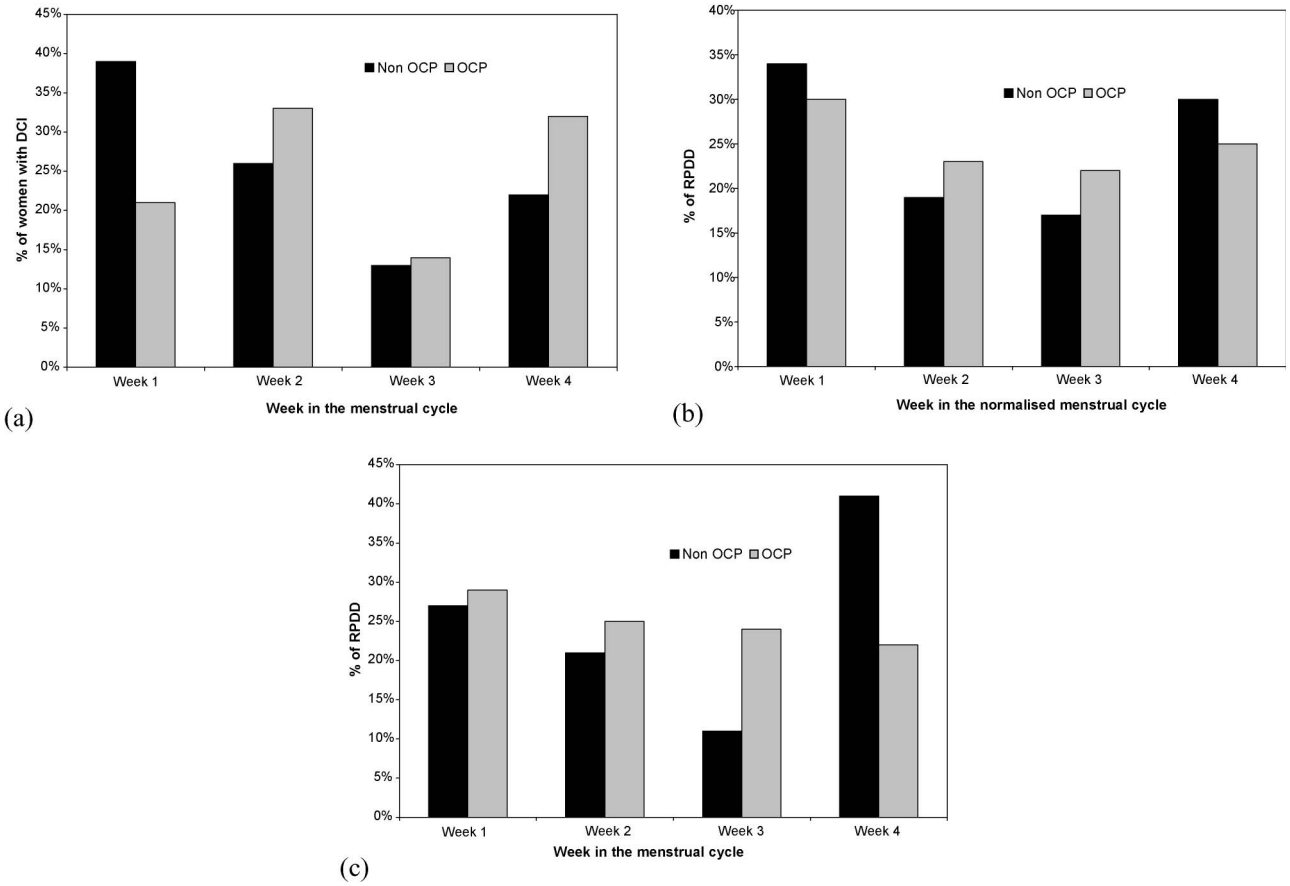

Figure 4. Lee et al. 2003, Decompression illness (DCI) data compared with the Diving Diseases Research Centre (DDRC) data, reported problems during diving (RPDD). (a) Lee et al. 2003, Normalised data DCI, (b) DDRC normalised data (RPDD), (c) DDRC data 28 day cycles only (RPDD).

Rudge 1990; Dunford and Hampson 1992; Krause et al. 1998; Lee et al. 2003). Our findings, relating to RPDDs, replicate the pattern seen by Lee et al. (2003) with regard to the non-OCP group (Figure 4). Lee et al. (2003) employed a strict inclusion criterion with data drawn only from physician confirmed and treated DCI and taken from a different study population. Although the remaining studies in Table II (Dixon et al. 1988; Rudge 1990; Dunford and Hampson 1992; Krause et al. 1998) are from smaller sample groups, retrospective records, or relate to altitude studies, the findings were similar with uneven distribution of events across the menstrual cycle. Our study supports the findings of the studies in Table II, namely that there appears to be a risk factor associated with menses and diving; additionally it was conducted with large numbers, over a long time scale and gathered data relating to RPDD rather than DCI *per se*.

The case for further research

With more women seeking careers in the diving industry and working as hyperbaric chamber attendants/nurses, there may exist a safety issue that warrants further review. While it is not possible to establish a causal link between the occurrence of RPDD in menstruating women and the position in the menstrual cycle, our study data indicate a clear correlation in both the normalised and 28-day data sets in this study population. It is not within the scope of this study to define whether the effects seen in this study group are due to hormone fluctuations that may offer a protective influence in the 3rd week, or constitute a risk factor in the 1st and 4th weeks. These data represent the largest published longitudinal, prospective field study of diary data over an extended period of time from female recreational divers, and as such provide an important platform for physiologically based studies.

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References

Bangasser S. 1978. Medical profile of the women scuba diver. In: National Association of Underwater Instructors. Proceedings of the 10th International Conference on Underwater Education. Colton, CA: NAUI. pp 31–40.

Bassett BE. 1980. Twelve year survey of the susceptibility of women to altitude decompression sickness. Pre-prints of the Aerospace Medical Association Annual Scientific Meeting. Alexandria, VA: Aerospace Medical Association. p 12–13.

Cooper GS, Sandler DP, Whelan EA, Smith KR. 1996. Association of physical and behavioural characteristics with menstrual cycle patterns in women age 29–31 years. Epidemiology 7:624–628.

Dawe F, Meltzer H, editors. 2001. Contraception and sexual health. In: Contraceptive use among women aged under 50. London: Office of National Statistics. Available at: http://www.statistics. gov.uk (Accessed November 2003).

Diving Incidents Information. 2004. Statement for Press Inquiries by Clare Peddie, National Diving Officer. Diving Fatalities. Available at: http://www.bsac.org/techerv/incguide/intro.htm

Dixon GA, Krutz RW, Fischer MS. 1988. Decompression sickness and bubble formation in females exposed to a simulated 7.8 PSIA suit environment. Aviation, Space, and Environmental Medicine 59:1146–1149.

Dunford RG, Hampson NB. 1992. Gender-related risk of decompression sickness in hyperbaric chamber inside attendants: A Case Control Study. Undersea Biomedical Research 19(Suppl):37.

Fife W. 1989. Women in diving: second study. In: Dennis GD, editor. Diving physiology and technology. Proceedings of the 10th Meeting of the United States–Japan Cooperative Program in Natural Resources (UJNR), 4–7 June. Kauai, Hawaii: UJNR. pp 19–38.

Guyton AC, Hall JE, editors. 1997. Female physiology before pregnancy; and the female hormones. In: Human physiology and mechanisms of disease. Philadelphia: Saunders. p 658-669.

Hausmann M, Slabbekoorn, Van Goozen SH, Cohen-Kettenis PT, Gunturkun O. 2000. Sex hormones affect spatial abilities during the menstrual cycle. Behavioral Neuroscience 114:1245–1250.

Krause KM, Pilmanis AA, Webb JT. 1998. The effect of menstrual day on decompression sickness (DCS) incidence in female research subjects. Aviation, Space, and Environmental Medicine 69:199.

Lee VM, St Leger Dowse M, Bunting AJ, Edge CJ. 1998. The menstrual cycle and decompression illness: What are the risks? Undersea and Hyperbaric Medicine 25(Suppl):11.

Lee V, St Leger Dowse M, Edge C, Gunby A, Bryson P. 2003. Decompression sickness in women: A possible relationship with the menstrual cycle. Aviation, Space, and Environmental Medicine 74:1177–1182.

Maki PM, Rich JB, Rosenbaum RS. 2002. Implicit memory varies across the menstrual cycle: Estrogen effects in young women. Neuropsychologia 40:518–529.

Mumenthaler MS, O'Hara R, Taylor JL, Friedman L, Yesavage JA. 2001. Relationship between variations in estradiol and progesterone levels across the menstrual cycle and human performance. Psychopharmacology (Berl) 155:198–203.

NDC Diving Incidents Report. 1999. Brian Cummings, Diving safety and incident advisor. Available at: http://www.bsac.org/techserv/increp99/intro.htm

Ross C, Coleman G, Stojanovska C. 2003. Prospectively reported symptom change across the menstrual cycle in users and non-users of oral contraceptives. Journal of Psychosomatic Obstetrics and Gynaecology 24:15–29.

Rudge FW. 1990. Relationship of menstrual history to altitude chamber decompression sickness. Aviation, Space, and Environmental Medicine 61:657–659.

Sibley P, Vankrieken L, Durham AP, Ei Shami AS. 1999. Impact of the menstrual cycle on BR-MA (CA15-3) and OM-MA (CA125) values, as determined by automated chemiluminescent assays on the immulite analyser [abstract 385]. Clinical Chemistry 45:A109.

St Leger Dowse M, Bryson P, Gunby A, Fife W. 2002. Comparative data from 2250 male and female sport divers: Diving patterns and decompression sickness. Aviation, Space, and Environmental Medicine 73:743–749.

St Leger Dowse M, Gunby A, Moncad R, Bryson P. 2003. The perceived effect of menstruation on diving incidents: a three-year prospective observational study. Undersea and Hyperbaric Medicine 30(Suppl):41.

St Leger Dowse M, Bryson P, Gunby A, Fife W. 2004. A prospective field study of reverse dive profiles in UK female recreational divers. South Pacific Underwater Medicine Society Journal 30:183–188.

Taylor MB. 1997. Women in diving. In: Bove AA, editor. Bove and Davis' diving medicine. 3rd ed. Philadelphia: Saunders. pp 89–107.

Treloar AE, Boynton RE, Behn BG, Brown BW. 1967. Variation of the human menstrual cycle through reproductive life. International Journal of Fertility 12:77–126.

Vann RD, Uguccioni D, editors. 2000. 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.

Willson JR, Blessed WB, Blackburn JP. 1983. Effect of repeated hyperbaric exposures on the menstrual cycle; preliminary study. Ann Arbor, MI: University of Michigan Medical School Michigan Sea Grant Project R/WS–2 MICHU–SG–84–306.

Zwingelberg KM, Knight MA, Biles JB. 1987. Decompression sickness in women divers. Undersea Biomedical Research 14:311–317.