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 4-6 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; Basset 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
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 5–21 days or 44–40 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 = \( \frac{28 \times D}{L} \), 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 ≥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...
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 postmenopausal 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; Dixon et al. 1988; Rudge 1990; Dunford and Hampson 1992; Krause et al. 1998; Lee et al. 2003).

### Table I. Fixed option reported problems during diving

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

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

<table>
<thead>
<tr>
<th>Menstrual cycle and DCS studies (see refs)</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dixon et al. 1988</td>
<td>All 5/30 female subjects with hypobaric DCS were in menses or early phase of cycle</td>
</tr>
<tr>
<td>Rudge 1990</td>
<td>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</td>
</tr>
<tr>
<td>Dunford and Hampson 1992</td>
<td>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)</td>
</tr>
<tr>
<td>Krause et al. 1998</td>
<td>Correlation between menstrual day and DCS: greatest probability being on day 2 of bleed; 62 retrospective records</td>
</tr>
<tr>
<td>Lee et al. 2003</td>
<td>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</td>
</tr>
</tbody>
</table>

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


