Nutrition for Synchronized Swimming: A Review

Bronwen Lundy

Synchronized swimming enjoys worldwide popularity and has been part of the formal Olympic program since 1984. Despite this, relatively little research has been conducted on participant nutrition practices and requirements, and there are significant gaps in the knowledge base despite the numerous areas in which nutrition could affect performance and safety. This review aimed to summarize current findings and identify areas requiring further research.

Uniform physique in team or duet events may be more important than absolute values for muscularity or body fat, but a lean and athletic appearance remains key. Synchronized swimmers appear to have an increased risk of developing eating disorders, and there is evidence of delayed menarche, menstrual dysfunction, and lower bone density relative to population norms. Dietary practices remain relatively unknown, but micronutrient status for iron and magnesium may be compromised. More research is required across all aspects of nutrition status, anthropometry, and physiology, and both sports nutrition and sports medicine support may be required to reduce risks for participants.

Keywords: aesthetic sport, female athlete, aquatic, disordered eating

Synchronized swimming is governed by the Fédération Internationale de Natation (FINA) and was first introduced to the Olympic program as a demonstration sport in 1948. It became part of the formal Olympic program in 1984, initially with the solo and duet and later with the team event replacing the solo discipline. The Olympic Games is the major competition, and at this level competition is limited to female participants. Both the team and duet disciplines have two events, these being the free and technical routines. The technical routine is composed of 6–10 required elements in a predetermined order and lasts 2 min 20 s for the duet and 2 min 50 s for the team. The free routine allows more flexibility to demonstrate interpretation of the music and skill. It is longer in duration (3 min 30 s for the free duet and 4 min for the team; FINA, 2009). Scoring is undertaken by two judging panels, with results split between technical and artistic merit. Technical scoring is made up of the technical execution of all moves, including aspects such as the height of the body out of the water, synchronization with team members and to the music, and level of difficulty, whereas the artistic score is made up of choreography, music interpretation, and the manner of presentation (FINA, 2009).

Synchronized swimming combines aerobic and anaerobic fitness, endurance, flexibility, strength, power, acrobatic and performance skills, and choreography, requiring long hours of training to attain such broad attributes (Mountjoy, 1999). This is similar to other aesthetic sports such as gymnastics and figure skating, which have been more extensively researched and can provide insights on issues that may be relevant in synchronized swimmers. The age of commencement is significant given the potential link between low energy intake in female athletes, delayed growth, and onset of puberty at the critical time for the development of peak bone mass (Nattiv et al., 2007; Rauh, Nichols, & Barrack, 2010). Eating disorders have also been linked with participation in aesthetic sports and commencement of sport-specific training at an early age (Davison, Earnest, & Birch, 2002).

Given the inclusion of the sport in the Olympic program and the complex attributes required for elite performance, it is surprising that nutrition for synchronized swimming remains relatively unexplored and that there is little known regarding either the nutrition practices or the nutrition requirements of the athletes. This review seeks to summarize current knowledge in the area of synchronized swimming where available and to identify areas for further research.

Training Patterns

At the elite level, a typical synchronized swimming training program may include 8–10 pool sessions per week including speed swimming, synchronized-swimming-specific skills, fitness, and strength. In addition there may be four sessions dedicated to improving flexibility, four to six sessions of cross-training, plus two to three resistance training. Overall it is a high-volume and high-intensity training program (Mountjoy, 2009), with the exception of periods devoted to choreography when much time may...
be spent in the pool but with limited energy expenditure (Price & Carlsen, personal communication).

Liang, Arnaud, Hatch, and Moreno (2005) found that the U.S. Olympic team trained 1,690 hr/year, compared with around 1,000 for similar standard gymnasts. Unfortunately, they did not specify the gymnastics discipline. The additional hours of training may be required to perfect synchronization (Mountjoy, 2008). The practical implications of these additional hours are very long training days with limited break times, potentially making it difficult for athletes to take in adequate energy and fluids, as well as presenting challenges juggling commitments to education, travel to and from training, and appointments with support staff such as medicine, physiotherapy, and nutrition. These factors may affect the athletes’ ability to follow an appropriate diet, as well as adequately rest, sleep, and recover from training.

Pazikas, Curi, and Aoki (2005) monitored the Brazilian synchronized swimming duo during a training camp for the Athens Olympics. They completed a 198-min training session in which 18% was performed at a light intensity (35–54% maximal heart rate [HRmax]), 53% at a moderate intensity (55–69% HRmax), 27% at a high intensity (70–89% HRmax), and 2% at a very high intensity (≥90% HRmax). The usefulness of these descriptive data is limited, however, because the authors used an estimated HRmax which may have been significantly different from the actual HRmax of the 2 subjects tested. Furthermore, the validity of HR data for monitoring synchronized swimming is questionable given the apneic bradycardia that occurs during routines (Bjurström & Schoene, 1987). During the session the duo lost 2% body weight, had a 30% fall in blood glucose, and increased β-hydroxybuturate levels despite consuming breakfast before training. They also had an increase in salivary and plasma cortisol (22% and 29%, respectively). The athletes consumed only water during the long session, taking in no additional carbohydrate, which may explain the reductions in blood glucose and increased ketone body finding. The timing and composition of meals and snacks and indeed the timing of blood glucose and ketone body measurements were not specified in the article, making it difficult to interpret.

### Physiological Requirements of the Sport

There is limited information available on the physiological stresses generated during synchronized swimming and the physiological profile of the athletes themselves. This is partly because of the challenges of taking measurements in the pool, especially when so much time, up to 50%, is spent underwater (Homma, 1994). Table 1 provides a summary of published physiological testing data on synchronized swimmers. It is difficult to make any generalization about these results given the differences in the tests conducted and the methodologies. The validity of this research for current synchronized swimmers may be further limited because the sport has since changed to become more athletic with the addition of acrobatic elements, increased speed of movement, a requirement for more power, and a greater level of complexity and difficulty in the routines (Price & Carlsen, personal communication).

Yamamura et al. (2000) tested team athletes for both the free and technical routines using trained (VO2max 51.6 ml · kg⁻¹ · min⁻¹) college female synchronized swimmers. They staged measurements to determine the capillary blood lactate levels at four points during the routine. The lowest blood lactate levels were found for the first stage of the technical routine and second stage of the free routine. The highest blood lactate concentration was found after the fourth stages of both the free and technical routines, indicating an accumulation of blood lactate with performance time. Yamamura et al. (2000) concluded that endurance training would support synchronized swimming performance by enhancing lactate removal and recovery of creatine phosphate. The small sample size of that study (N = 4) and the limited range of physiological parameters measured (VO2max and blood lactate) make interpreting these findings difficult.

Other physiological findings include those from Yamamura et al. (1999), who found a significant correlation between aerobic capacity and synchronized swimming performance scores. They also noted a correlation between performance scores and isokinetic muscle strength of elbow extension and flexion, knee extension, abdominal muscle endurance, leg extension power, and swimming velocity at the onset of blood lactate accumulation. Yamamura et al. (1998) found that rating of perceived exertion by the final stage of the routine was 17.7 ± 0.8, indicating that the synchronized swimmers found it very hard (Borg, 1998). The physiological testing results suggest that the synchronized swimmers had a moderate level of aerobic fitness and perhaps relied on other areas of physiological adaptation for elite synchronized swimming performance.

A unique aspect of synchronized swimming is the amount of time spent holding the breath to perform maneuvers underwater. Bjurström and Schoene (1987) demonstrated that elite synchronized swimmers had higher total lung capacity and vital capacity than controls. The hypoxic ventilatory response was lower and higher total lung capacity and vital capacity than controls. The hypoxic ventilatory response was lower and higher total lung capacity and vital capacity than controls.

<table>
<thead>
<tr>
<th>Subject</th>
<th>VO2max (ml · kg⁻¹ · min⁻¹)</th>
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<tbody>
<tr>
<td>Female synchronized swimmer</td>
<td>51.6</td>
</tr>
</tbody>
</table>

Yamamura et al. (2000) undertook laboratory trials comparing synchronized swimmers with control subjects, testing first with free respiration then with alternating periods of apnea and free respiration for 15-s intervals during 4 min on a cycle ergometer at 1.5
Table 1  Summary of Physiological Findings in Synchronized Swimmers

<table>
<thead>
<tr>
<th>Researchers</th>
<th>N</th>
<th>Age, years</th>
<th>Subjects</th>
<th>Conditions</th>
<th>VO$<em>{2\text{max}}$ or VO$</em>{2\text{peak}}$, ml · kg$^{-1}$ · min$^{-1}$</th>
<th>Blood lactate, mM</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yamamura, Matsui, &amp; Kitagawa, 2000</td>
<td>4</td>
<td>19.6 ± 1.4</td>
<td>Trained college level</td>
<td>Team data (free &amp; technical), VO$_{2\text{max}}$ test in swimming flume</td>
<td>51.6 ± 1.5 (VO$_{2\text{max}}$)</td>
<td>10.2 ± 1.1 (peak)</td>
<td></td>
</tr>
<tr>
<td>Bante, Bogdanis, Chairopoulou, &amp; Maridaki, 2007</td>
<td>8</td>
<td>21.6 ± 0.9</td>
<td>Senior national-level athletes</td>
<td>VO$_{2\text{peak}}$ using an incremental 400-m front-crawl swimming test, simulated synchronized swimming routine</td>
<td>45.7 ± 2.4 (VO$<em>{2\text{peak}}$) 81% of VO$</em>{2\text{peak}}$ at end of routine</td>
<td>5.7 ± 0.9 (post-routine)</td>
<td>Peak heart rate 87.1% ± 0.9% of maximum, EPOC 41.3 ± 4.3 ml O$_2$/kg 3 min monitoring post-routine, breathing frequency 30.2 ± 2.2 breaths/min; data expressed as $M ± SE$</td>
</tr>
<tr>
<td>Chatard, Mujika, Chantegraille, &amp; Kostucha, 1999</td>
<td>13</td>
<td>14 ± 1 years</td>
<td>Highly trained</td>
<td>VO$_{2\text{peak}}$ using a 400-m swim-based test</td>
<td>52.4 ± 4.9 (VO$_{2\text{peak}}$)</td>
<td>7.5 ± 1.6 (post-routine)</td>
<td>400-m swim time 385 ± 23.9 s</td>
</tr>
<tr>
<td>Poole, Crepin, &amp; Sevigny, 1980</td>
<td>32</td>
<td>16.6 ± 5.9</td>
<td>Elite, including juniors ($n = 10$) and seniors ($n = 22$)</td>
<td>VO$_{2\text{max}}$ using a continuous treadmill test to exhaustion</td>
<td>44.4 ± (VO$_{2\text{max}}$) 4.4</td>
<td>Not specified whether data were expressed as $M ± SD$ or $SE$</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Data expressed as $M ± SD$ unless noted otherwise.
have a low body weight, and those boosting, who push or
and athletic appearance and a high level of uniformity of
physique within the team or duo (Price & Carlsen, per-
and athletic appearance and a high level of uniformity of
personal communication).
creates more height and more speed (Price & Carlsen,
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limbs are desirable attributes for synchronized swimmers,
& Carter, 2006). Anecdotal reports suggest that longer
which likely precludes high muscularity or very low
importance of acrobatics and the need for buoyancy,
swimming, but the picture is complicated by the lesser
research measuring full anthropometric profiles of elite
swimmers be undertaken. Limb lengths and
istics for the sport.

Physique

Limited data are available on the anthropometric char-
characteristics of elite synchronized swimmers, and as such
the optimal physique has not yet been described. This
is in contrast with similar sports such as artistic and
rhythmic gymnastics in which more research has been
undertaken. Female gymnastic performance is strongly
affected by height and weight, giving clear parameters for
the selection of athletes (Claessens, Lefevre, Beunen, &
Malina, 1999). To an extent this is true in synchronized
swimming, but the picture is complicated by the lesser
importance of acrobatics and the need for buoyancy,
which likely precludes high muscularity or very low
body-fat levels (Price & Carlsen, personal communi-
cation). A summary of available data on physique of
synchronized swimmers is found in Table 2. Height is
similar to population norms, but body weight and body-
mass index (BMI) are low (Bante et al., 2007). This is
similar between all data sets shown and may suggest a
preferred size and build of athletes, being average height
with a low body weight relative to height. Unfortunately
it is not possible to compare body-fat data because of
the varied methods used, despite a clear international
standard being available (Marfell Jones, Olds, Stewart,
& Carter, 2006). Anecdotal reports suggest that longer
limbs are desirable attributes for synchronized swimmers,
with long lean legs appearing to achieve more height out
of the water and longer arms for better sculling, which
creates more height and more speed (Price & Carlsen,
personal communication).

It appears to be desirable in this sport to have a lean
and athletic appearance and a high level of uniformity of
physique within the team or duo (Price & Carlsen,
personal communication). In addition, those involved in
the acrobatic components have more specific requirements.
Those being thrown during acrobatic maneuvers need to
have a low body weight, and those boosting, who push or
support the athlete performing figures from underneath,
may have an increased strength requirement. Bante et
al. (2007) found that national-team Greek athletes had
a higher lean leg cross-sectional area than junior-level
athletes, as well as a significant correlation with per-
formance scores ($r = .84, p < .05$), possibly indicating
that leg muscularity is a specific adaptation to the sport.

Dietary Practices and Nutrition Requirements

To date, the dietary practices of elite synchronized swim-
mers remain relatively unexplored. Although it is possible
to loosely extrapolate dietary patterns from other aesthetic
sports such as figure skating or gymnastics, the unique
training patterns and physique requirements of synchro-
nized swimming warrant their own study.
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</thead>
<tbody>
<tr>
<td>N</td>
<td>14</td>
<td>8</td>
<td>21</td>
<td>33</td>
<td>N/A</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Age (years)</td>
<td>N/A</td>
<td>22.6 ± 0.9</td>
<td>17.1 ± 1.9</td>
<td>17.3 ± 2.2</td>
<td>N/A</td>
<td>21 ± 0.5</td>
<td>19.8 ± 2.8</td>
</tr>
<tr>
<td>Standard</td>
<td>National team</td>
<td>National team</td>
<td>National team</td>
<td>College</td>
<td>National team</td>
<td>National team</td>
<td>National team</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.4 ± 8.7</td>
<td>167.5 ± 1.1</td>
<td>165 ± 7.0</td>
<td>166 ± 5.0</td>
<td>165</td>
<td>168 ± 0.7</td>
<td>159 ± 3.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>57.3 ± 8.2</td>
<td>56.8 ± 1.2</td>
<td>55.7 ± 6.9</td>
<td>54.5 ± 4.9</td>
<td>55.2</td>
<td>61.2 ± 0.7</td>
<td>52.5 ± 2.7</td>
</tr>
<tr>
<td>Body-mass index (kg/m²)</td>
<td>20.4</td>
<td>20.2 ± 0.3</td>
<td>20.4 ± 1.5</td>
<td>19.8 ± 1.5</td>
<td>20.9</td>
<td>21.6 ± 0.7</td>
<td>20.7 ± 0.7</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>16.2 ± 3.6a</td>
<td>21.4 ±0.8b</td>
<td>23.6 ± 3.8c</td>
<td>N/A</td>
<td>19.8a</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Skinfolds (mm)</td>
<td>87.3 ± 26.3</td>
<td>76.1 ± 4.9</td>
<td>41 ± 8.6</td>
<td>N/A</td>
<td>N/A</td>
<td>78.1 ± 0.7</td>
<td>N/A</td>
</tr>
<tr>
<td>(sum of 6 sites)</td>
<td></td>
<td>(sum of 6 sites)</td>
<td>(sum of 4 sites)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somatotype (endo-meso-ectomorph)</td>
<td>N/A</td>
<td>2.9-1.9-3.4</td>
<td>N/A</td>
<td>N/A</td>
<td>3.8-3.3-3.2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note. All are presented as $M \pm SD$ except Greek and U.S. data, which are $M \pm SE$.

Energy Intake and Eating Behaviors

Ebine et al. (2000) conducted the only well-controlled study of energy expenditure in synchronized swimming, using doubly labeled water to determine energy expenditure for 9 Japanese national-team athletes (4 seniors and 5 juniors). Mean energy expenditure was 2,738 ± 672 kcal/day (52.2 kcal · kg⁻¹ · day⁻¹), and self-reported energy intake was 2,128 ± 395 kcal/day (40.5 kcal · kg⁻¹ · day⁻¹), with physical activity level determined as 2.18. Given that the athletes were weight stable during the study period, there appeared to have been significant underreporting (energy intake 77.7% of total energy expenditure). A degree of underreporting is expected in athletic populations (Burke, 2001), and it is known to be particularly problematic in aesthetic sports (Fogelholm et al., 1995). Ebine et al.'s study provides insights into the Japanese national team, but, because there was no description of the training they undertook, it is not possible to extrapolate to other countries or settings where the training styles and intensities may be very different. This study does indicate that underreporting should be considered when assessing dietary-intake data for synchronized swimmers.

Comparative energy-intake data are available from similar activities such as figure skating, gymnastics, and ballet. Ziegler, Nelson, and Jonnalagadda (1999) reported 1,536 kcal/day (33 kcal · kg⁻¹ · day⁻¹) for figure skaters, and Soric, Misigoi-Durakovic, and Pedisic (2008) reported daily energy intake of 63.4 ± 28.7 kcal/day for artistic gymnasts, 44.9 kcal/day for rhythmic gymnasts, and 51.4 ± 16.6 kcal/day for ballet dancers. Soric et al. used parents to report on food intake to minimize underreporting and collected dietary data using a quantitative food-frequency questionnaire rather than diet records. This may account for the higher energy intake in their study, but other variables such as differences in energy requirements through age, weight, or training intensity and duration may also have an impact.

An interesting point to consider is the known effect of cool-water immersion on voluntary energy intake. White, Dressendorfer, Holland, McCoy, and Ferguson (2005) examined the effect of energy expenditure and voluntary postexercise energy intake in three conditions: a control condition with no water immersion, cool water (20 °C), or “neutral” water (33 °C). They found no differences in energy expenditure based on the different conditions, but when immersed in cool water, they consumed 44% and 41% more energy than the neutral and control conditions, respectively. This could have a considerable impact on the success of athletes trying to restrict energy intake or maintain energy balance and also suggests that pool temperature should be reported in studies relating to swimmers’ energy intake.

With respect to eating behaviors it would be interesting to know whether the impact of body positioning during training, such as spending a significant amount of time upside down, causes gastrointestinal discomfort and influences the athletes’ food selection, particularly given the early morning start to training, likely soon after breakfast.

Micronutrients

A recent position paper on nutrition and athletic performance (Rodriguez et al., 2009) identifies calcium, vitamin D, B vitamins, iron, zinc, magnesium, and antioxidants such as vitamins C and E, β-carotene, and selenium as most deficient in athletic populations. Only a few of these nutrients have been investigated in synchronized swimming.

Roberts and Smith (1990) measured serum ferritin in a group of elite Canadian synchronized swimmers over the course of two seasons and demonstrated a drop during the study period (from 48 ± 10 to 24 ± 6 μg/L). There was also a significant decrease in hemoglobin. The Great Britain (GB) synchronized swimming squad was screened (Rossiter, unpublished study, 2009) for a number of blood markers during a heavy phase of training in 2008–09. The squad had two swimmers competing at an international level and was ranked in the top 15. The remaining 10 swimmers were aspiring to international competition, with 8 of these successful within 2 years of the data collection. In this group mean serum ferritin was 43.7 ± 33.1 μg/L, with 6% of the athletes having results lower than the reference range and a further 28% of the athletes tested having levels below 25 μg/L, identifying them as borderline or at risk for low ferritin stores. This is low compared with data collected from female figure skaters, which revealed normal iron status and mean serum ferritin results of 61 ± 30 μg/L (Ziegler et al., 1999). Iron depletion (defined as <12 μg/L serum ferritin) without anemia decreases VO₂max even with normal hemoglobin (Zhu & Haas, 1997) and may have a significant effect on performance. Iron deficiency and iron-deficiency anemia are known to negatively affect immune function in athletes (Gleeson, Nieman, & Pedersen, 2004), but what remains unclear is the effect of borderline iron stores and therefore the significance of these at-risk findings in synchronized swimmers.

The GB squad’s mean for serum magnesium status was normal (0.88 ± 0.1 mmol/L), but 26% of athletes tested had results lower than the reference range (Rossiter, unpublished study, 2009). Given the known limitations of current assessment techniques for magnesium status and the acute changes in serum magnesium that occur after exercise, interpretation of this finding is difficult. In a review on magnesium and exercise, Nielsen and Lukasiki (2006) suggested that low magnesium status may reduce exercise performance and amplify oxidative stress, although to date most of the available research has been conducted using animal models and there are limited human data. Folate, B₁₂, and vitamin D status were all normal for the GB squad (Rossiter, unpublished study, 2009). Zinc, selenium, other B vitamins, vitamin C, and β-carotene were not measured. No further studies appear to have been done regarding micronutrient intake or status in this group. It would be interesting to
investigate whether there is any selection or judging bias toward either tanned or pale skin in the sport, given the potential for skin pigmentation to affect vitamin D status. Anecdotal reports indicate a high use of tea and coffee in early-morning and weight-restricted sports, and, given their polyphenol content and potential to interfere with iron status (Hurrell, Reddy, & Cook, 1999), it would be interesting to investigate whether consumption is linked with iron status in synchronized swimmers.

Studies looking at micronutrient intake have been conducted in similar sports such as figure skating and rhythmic gymnastics. Jonnalagadda, Ziegler, and Nelson (2004) found that elite female figure skaters had dietary intakes of less than 60% of the recommended intakes for vitamins E and D, pantothenic acid, folate, calcium, magnesium, potassium, and phosphorus, but because no measures of status were taken it is unknown whether this resulted in deficiency. Cupisti, D’Alessandro, Castrogiovanni, Barale, and Morelli (2000) found similarly poor intakes of copper, zinc, iron, phosphorus, and calcium in a group of elite rhythmic gymnasts. With the exception of zinc and phosphorus, which were lower in the gymnast group, the findings were paralleled in an age-control group. This suggests that either a 3-day diary was inadequate to accurately represent micronutrient intake or participation in rhythmic gymnastics had little influence on micronutrient intake.

Hydration

In field studies 50% of the GB team arrived at training dehydrated, defined as urine specific gravity ≥1.020, with a mean urine specific gravity of 1.021 ± 0.004 (SD). Sweat losses during the two sessions monitored (240 min of land training and 180 min of synchronized swimming training) were small (258 ± 49 ml/hr during the land session and 204 ± 60 ml/hr during the pool session). Fluid replacement was 78% during the land session and 59% during the pool session, meaning the athletes were on average 0.4% ± 0.5% dehydrated (unpublished study, Brown & Lundy, 2008) and unlikely to show a performance decrement (American College of Sports Medicine et al., 2007). This is in contrast with the findings of Pazikas et al. (2005), who showed a 2% loss during an Olympic training camp session, most likely as a result of differences in environmental conditions and training intensity.

It is interesting to note the lower fluid replacement during pool sessions, possibly because of limited drink breaks or potentially to avoid gastrointestinal upset if practicing moves requiring the athlete to be upside down.

Disordered Eating and Eating Disorders

Although some athletes naturally achieve the lean and athletic appearance valued in synchronized swimming, for others, attaining these physique characteristics may be difficult and require chronic energy restriction. It is unclear whether this energy restriction or some other factor may contribute to the risk of developing disordered eating or eating disorder, but it is apparent in the literature that the risk is greater in aesthetic sports than in others (Sundgot-Borgen & Torstveit, 2004). Douka, Skordilis, Koutsouki, and Theodorakis (2008) used the EAT13 and BMI assessment to identify eating-disorder risk in female national-team athletes in aquatic sports (water polo, swimming, and synchronized swimming). Synchronized swimmers were found to have significantly higher scores on two out of three of the EAT scales than swimmers or water polo players. The EAT13 is a shortened version of the EAT26 questionnaire, which excluded questions about bulimia and may therefore be a less suitable tool to use in this population. Similarly, Lee (2005) used the EAT26, the Body Dissatisfaction Index, 3-day food records, and surveys on weight-control behavior and menstrual status to assess female elite athletes in seven sports. EAT26 scores were not different among sports, but eating disturbances (EAT scores ≥20) were highly prevalent in aesthetic sports (synchronized swimming and rhythmic gymnastics), with an incidence of 30% compared with just 5% in the other sports.

Ferrand et al. (2007) used a range of questionnaires to look at restraint, perfectionism, body esteem, anthropometry, eating behavior, and weight-control techniques in a group of top-level college synchronized swimmers. Of those studied, more than half (54.5%) considered themselves overweight despite falling well within the healthy weight range. Weight-loss methods included limiting food choice, very low fat intakes, reducing volume, self-induced vomiting (24.2%), fasting (24.2%), diuretics (15.3%), and laxatives (3.3%). Many (27.2%) also indicated that they used intensive exercise to lose weight, in addition to the planned squad training of 24 hr/week. The greatest pressure to lose weight was reported as coming from teammates (57.5%), followed by coaches (36.3%). Ferrand, Magnan, and Philippe (2005) used the EAT26 and a body-esteem scale with 42 elite adolescent synchronized swimmers matched with a nonaesthetic sport and nonathlete controls. The synchronized swimmers reported greater negative feelings about their appearance and low perceptions of how others evaluate their physical appearance relative to the both control groups.

A study of senior (national-team) and junior synchronized swimmers in Brazil found that the incidence of disordered eating, body dissatisfaction, and eating disorders was much higher in the junior team than the senior team, possibly because of the availability of nutrition advice for seniors (Perini et al., 2009) or because those with eating disorders do not make it to the senior levels. It is also possible that junior athletes face more selection pressure trying to make it to the senior levels, causing them to go to great lengths to achieve the necessary physique (Ferrand et al., 2005).

Despite the various methods used, the research that has been conducted is unanimous in suggesting an increased risk of eating disorder in synchronized swimmers, and both nutritional and medical support may be required to minimize risk for athletes participating in this sport.
sport. Further research would be best targeted at identifying the risk factors specific to this sport to maximize prevention.

**Bone Health and Menstrual Status**

Athletes from aesthetic sports are known to be more likely to experience impaired menstrual function, with its contributory risk to osteoporosis (Constantini & Warren, 1995). Sambanis et al. (2003) compared the menstrual history of athletes from a variety of sports using a self-report questionnaire and found a delay in menarche of 0.6 years for synchronized swimmers compared with all other sports except gymnastics, in which there was a delay of 1.7 years. Gymnasts and synchronized swimmers had the lowest rating of menstrual-cycle stability, but no data were reported on amenorrhea or other aspects of menstrual dysfunction. Ramsay and Wolman (2001) looked at menstrual status of the GB national team and found that only 3 of 23 (13%) of team members were oligomenorrheic and none were amenorrheic; however, that research was conducted before the formation of a fully fledged national program, and it is possible that the athletes were not training at an elite standard. Furthermore, 5 athletes (21%) were taking the oral contraceptive pill, which would mask symptoms of amenorrhea that may otherwise have been present. Ferrand et al. (2007) found that 30.3% of synchronized swimmers reported menstrual dysfunction, but most of the rest of the study group (63.6%) were taking the oral contraceptive pill so the true incidence is unknown.

Liang et al. (2005) used bone stiffness in the tibia and ulna as an index of bone strength in Olympic-level synchronized swimmers, gymnasts of national or Olympic standard, and untrained age-matched controls. Both gymnasts and synchronized swimmers had bone stiffness nearly twice that of the control group. This was a surprise given the high-impact nature of gymnastics relative to swimming, which is weight supported. Liang et al. speculated that the higher than expected bone stiffness of the synchronized swimmers was caused by the repetitive high-velocity muscle-contracile force that is a feature of the sport. It is also important to note that these synchronized swimmers were eumenorrheic, which may represent a best-case scenario for bone stiffness in the sport. In the same study, bone-mineral density measured in the wrist was lower in the synchronized swimmers than either the gymnasts or untrained controls, which may point to a higher risk of osteoporosis (Liang et al., 2005). The lower bone-mineral density relative to gymnasts is identified as deficient.

...whole-body measures. Bone age appeared to be delayed by around 1 year from chronological age. There were similar findings for female artistic gymnasts, with a delay of 2 years. Bone-mineral density was positively correlated with height, weight, BMI, lean and fat mass, and the age of onset of training and was negatively correlated with exercise intensity and duration (Markou et al., 2004).

From the current research it appears likely that menstrual status and bone health are adversely affected in synchronized swimming, but to what extent is unclear. Given the presence of menstrual dysfunction, delayed menarche, slowed bone age, and evidence of lower bone density, it would appear that further research is warranted in elite performers, relating measures back to clinical risk for the short and long term.

**Supplements That May Promote Optimal Performance in This Sport**

There do not appear to be any studies available on supplementation and synchronized swimming performance. Sports foods are likely to have the largest role in improving performance, provided they are used appropriately within the athlete’s energy budget. Sports drinks could be used to aid hydration and provide carbohydrate during long training sessions. Similarly, use of compact foods such as sports bars, sports drinks, or meal-replacement drinks may be of benefit during competition if events are close together or to provide energy without bloating and discomfort during maneuvers. A multivitamin supplement may be useful for energy-restricted or traveling athletes. As discussed previously iron, calcium, or magnesium supplements may be of benefit if an athlete is identified as deficient.

**Conclusions**

Synchronized swimming is a complex sport that remains relatively unexplored in the literature. Many of the studies conducted had methodological limitations or were conducted before significant rule changes were in place affecting the physiological and nutrition requirements of the sport. Focus should be placed on achieving coaches’ targets for physique safely and without compromising training quality or risking disordered eating. Further research is needed across most areas of nutrition for synchronized swimming. Suitable research questions might include the following:

- What are the physique characteristics of top performers in synchronized swimming? Does adiposity matter, or are shape characteristics and proportions more important?
- Do synchronized swimmers have a restricted energy intake, and is this reflected in suboptimal bone health, menstrual, or micronutrient status? What are their specific dietary requirements for optimal performance?
• How does the culture of synchronized swimming affect eating behaviors, nutrient status, and optimal practices with respect to training and competition diets?
• What are the modern physiological requirements of the sport for competition and training?
• Does the length of time in the water affect gastrointestinal tract function, energy expenditure, and core temperature and through these influence food selection and nutritional status?
• What are the sport-specific risk factors for developing adverse eating behaviors? At what developmental stage are preventive nutrition education strategies best implemented?

References


