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Energy Deficiency, Menstrual Disturbances, and Low Bone Mass: What Do Exercising Australian Women Know About the Female Athlete Triad?

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Purpose: Prevention of the female athlete triad is essential to protect female athletes' health. The aim of this study was to investigate the knowledge, attitudes, and behaviors of regularly exercising adult women in Australia toward eating patterns, menstrual cycles, and bone health. ***Methods:*** A total of 191 female exercisers, age 18–40 yr, engaging in ≥2 hr/wk of strenuous activity, completed a survey. After 11 surveys were excluded (due to incomplete answers), the 180 participants were categorized into lean-build sports (n = 82; running/athletics, triathlon, swimming, cycling, dancing, rowing), non-lean-build sports (n = 94; basketball, netball, soccer, hockey, volleyball, tennis, trampoline, squash, Australian football), or gym/fitness activities (n = 4). ***Results:*** Mean (± *SD*) training volume was 9.0 ± 5.5 hr/wk, with participants competing from local up to international level. Only 10% of respondents could name the 3 components of the female athlete triad. Regardless of reported history of stress fracture, 45% of the respondents did not think that amenorrhea (absence of menses for ≥3 months) could affect bone health, and 22% of those involved in lean-build sports would do nothing if experiencing amenorrhea (vs. 3.2% in non-lean-build sports, p = .005). Lean-build sports, history of amenorrhea, and history of stress fracture were all significantly associated with not taking action in the presence of amenorrhea (all p < .005). ***Conclusions:*** Few active Australian women are aware of the detrimental effects of menstrual dysfunction on bone health. Education programs are needed to prevent the female athlete triad and ensure that appropriate actions are taken by athletes when experiencing amenorrhea.

Keywords: amenorrhea, menstrual dysfunction, eating disorders, energy balance, bone-mineral density

The female athlete triad is a medical condition that affects active females worldwide (Nattiv et al., 2007). It includes three components: low energy availability, menstrual dysfunction, and low bone-mineral density (Nattiv et al., 2007). Low energy availability, which triggers the health complications associated with the female athlete triad (Beals & Meyer, 2007), usually results from an energy intake insufficient to match the energy expenditure induced by training. In the short term, detrimental health consequences include stress fractures, osteopenia, fatigue, and infertility, as well as impaired endothelial function (Hoch, Lal, Jurva, & Gutterman, 2007). In the longer term, former athletes who have suffered from the female athlete triad might be at increased risk of osteoporosis and cardiovascular disease (De Souza & Williams, 2004; Nattiv et al., 2007; Papanek, 2003). The prevalence of the complete condition is relatively low, with only 1–5% of female exercisers presenting with all three components (Beals & Hill, 2006; Nichols, Rauh, Lawson, Ji, & Barkai, 2006; Torstveit & Sundgot-Borgen, 2005a). However, one in four to one in five female athletes present with at least one component of the female athlete triad (Beals & Hill, 2006; Nichols et al., 2006; Torstveit & Sundgot-Borgen, 2005b), which places them at greater risk for developing the complete condition. Because treatment of the female athlete triad (and more generally, treatment of disordered eating) is known to be challenging, emphasis should be placed on preventing the condition through education (Nattiv et al., 2007; Otis, Drinkwater, Johnson, Loucks, & Wilmore, 1997). To design effective education programs, the knowledge, attitudes, and behaviors of female exercisers toward the female athlete triad must be better understood. To this end, an early American survey conducted in 189 female athletes showed that only one third of them were aware of the link between menstrual dysfunction and poor bone health (Simpson et al., 1998). Other American studies have investigated nutritional knowledge in female athletes but have various shortcomings, including failing to consider other components of the female athlete triad (menstrual dysfunction and poor bone health), having relatively small sample sizes (n < 100), and including only a limited number of sports (Chapman, Toma, Tuveson, & Jacob, 1997; Frederick & Hawkins, 1992; Raymond-Barker, Petroczi, & Quested, 2007; Wiita & Stombaugh, 1996; Zawila, Steib, & Hoogenboom, 2003).

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Competitive sports and, more generally, physical activity are organized differently between countries. For example, college athletes in the United States train and compete as professionals, while this is not the case in Australia. These differing competitive environments may result in different stressors or pressures to succeed at sport that may manifest differently in females in Australia than in their American counterparts. Perception and beliefs of young girls and women about exercise may also differ. Therefore, to be able to develop effective education programs to prevent the female athlete triad and raise awareness about the condition in Australia, the objectives of this study were to investigate the knowledge, attitudes, and behaviors of Australian adult female athletes and exercisers regarding the female athlete triad and its symptoms and to identify the factors that influence knowledge, attitudes, and behaviors toward the female athlete triad.

Materials and Methods

Participants

Women who engaged in regular exercise and were 18–40 years of age were invited to participate. Regular exercise was defined as currently engaging in strenuous physical activity at least three times per week for at least 2 hr in total per week.

Study Design

Each participant completed an anonymous survey with 45 questions assessing her knowledge, attitudes, and behaviors toward the female athlete triad. Completion of the survey, which was either electronic (Survey Methods software, 2009, Survey Methods Inc., Dallas, TX) or paper based, gave participants a chance to win one of three gift vouchers that were offered as incentives. Written informed consent was obtained from participants. Recruitment took multiple forms. Participants were recruited from sporting clubs and fitness centers throughout Melbourne (Victoria, Australia) that were selected by the research team via maximum-variation sampling to obtain a heterogeneous sample of sports and competition levels. One investigator (S.M.M.) contacted coaches and, with their agreement, met the athletes at training sessions and presented the survey. The same investigator also distributed flyers in fitness centers. The Victorian and Australian Institutes of Sport were invited to participate but declined due to the overwhelming demand for these institutes to participate in research projects. For the online surveys, e-mails were sent to clubs and fitness centers inviting them to participate. If an affirmative response was received, a Web link to the survey was sent for dissemination to club members who met the inclusion criteria. The procedures used in this study complied with the National Health and Medical Research Council of Australia's National Statement on Ethical Conduct in Human Research, and all procedures were approved in advance by the Human Research Ethics Committee of Deakin University.

Survey Instrument

The survey was a modification of a previous questionnaire (Simpson et al., 1998). In order for participants to disregard instances when they intentionally missed their menstrual period via use of an oral contraceptive pill or because of pregnancy, a note explaining questions on amenorrhea was included in the survey. The survey was reviewed by five experts (two local sports physicians, two researchers, and one physiotherapist based in the United States, all of whom have extensive expertise on the female athlete triad), further modified, and pilot tested in 6 female exercisers according to existing guidelines (Portney & Watkins, 2009). Five participants who were involved in pilot testing completed the survey twice, at least 1 week apart, to assess reproducibility. Reproducibility was not quantified because the survey included open-ended questions (approximately one third of the survey); instead, reproducibility was established based on expert judgment.

Statistical Analysis

Parameters were presented as percentages for categorical variables and $M \pm SD$ for continuous variables. Cross-tabulations with chi-square tests for independence were used to examine relationships between categorical variables (with Yates continuity correction for 2×2 cross-tabulations). Distribution of all continuous variables was non-Gaussian (determined using the Kolmogorov–Smirnov test), so nonparametric tests (Mann–Whitney U and Kruskal–Wallis) were used to investigate which factors affected knowledge, attitudes, and behaviors toward the female athlete triad. Post hoc tests and Bonferroni correction were applied where appropriate. A significance level of .05 was adopted. Knowledge, attitudes, and behavior were analyzed against the following factors to test for differences: sport type (lean-build vs. non-lean-build), age, level of competition, and previous history of stress fracture, disordered eating, or menstrual dysfunction. Only statistically significant differences were reported in the manuscript. Data were analyzed using SPSS version 17.0 (SPSS Inc., Chicago, IL).

Results

The survey was completed by 191 female exercisers. The first and second run of the pilot surveys completed by 5 athletes were assessed by the first author (S.M.M.) and the senior author (G.D.) and were considered in their expert judgment to have good reproducibility. Eleven participants were excluded because of missing demographic data. The final sample consisted of 180 respondents (132 paper surveys were distributed with a response rate of 60%; the other surveys were completed online) from 16 different sports: athletics/running (n = 34), basketball (n = 30), netball (n = 21), soccer (n = 17), hockey (n = 17), triathlon (n = 13), swimming (n = 11), cycling (n = 11), dancing (n = 9), rowing, fitness (gym-based), volley-ball, tennis, trampoline, squash, and Australian football (all $n \leq 4$).

Sports emphasizing body weight or lean physique (i.e., athletics/running, swimming, cycling, triathlon, dancing, rowing) were categorized as lean-build sports, while sports not necessarily emphasizing body weight or lean physique (i.e., basketball, netball, soccer, tennis, hockey, volleyball, squash, Australian football, trampoline) were categorized as non-lean-build sports, based on previous classifications (Beals & Hill, 2006).

Demographic characteristics of the participants are presented in Table 1. All participants met the eligibility criterion for exercise volume (≥2 hr/week, range 3–32 hr/week). Almost all participants who completed the survey were currently engaged in competition (96%). The proportions of respondents who reported a history of disordered eating (i.e., reporting at least two of the following behaviors on a weekly basis: fasting, self-induced vomiting, use of laxatives, use of diuretics), menstrual dysfunction (i.e., amenorrhea: missing three consecutive periods or more), and stress fracture (having sustained at least one stress fracture diagnosed by a medical doctor) are given in Table 1. Half the respondents reported never having experienced any component of the female athlete triad, with 39%, 11%, and 0.6% reporting that they had experienced one, two, and three components, respectively.

When asked, "Have you ever heard about the 'female athlete triad'? If yes, could you describe it?" 10% of the sample could name all three components of the triad (energy deficiency, menstrual dysfunction, and poor bone health). This was independent of type of sport (lean-build vs. non-lean-build), age, level of competition, and personal experience of components of the female athlete triad. Knowledge was further investigated by testing the participants' capacity to correctly identify each of the components (rapid weight loss, absent menses, and stress fractures) as a potential sign of energy deficiency. The concept of energy deficiency was introduced in the question as follows:

Table 1 Descriptive Parameters of the Female Exercisers Who Completed the Survey on the Female Athlete Triad

	Lean-build sports	Non-lean-build sports	Gym-based exercise	Total sample
n	82	94	4	180
Age category				
18–24 years	39%	64%*	50%	52%
25–30 years	26%	26%	25%	26%
31–40 years	35%	11%**	25%	22%
Training volume (hr/week)[a]	12.0 ± 6.2	6.3 ± 2.5**	8.5 ± 3.1	9.0 ± 5.5
Years of competing	8.1 ± 6.4	12.9 ± 5.5**	6.0 ± 4.2	10.8 ± 6.4
Engaged in more than one sport	59%	53%	75%	56%
Total volume of physical activity (hr/week)	13.3 ± 6.1	9.0 ± 3.5**	8.5 ± 3.1	11.0 ± 5.3
Highest level of competition				
international	19%	2%*	0%	10%
national	32%	19%	67%	25%
state	28%	67%**	0%	49%
local	21%	12%	33%	16%
Reported history regarding the female athlete triad				
disordered eating[b]	7%	11%	0%	9%
menstrual dysfunction[c]	46%	18%**	50%	32%
stress fracture	26%	20%	50%	23%

Note. Values are *M* ± *SD* or percentages. Lean-build sports included running/athletics, cycling, triathlon, swimming, rowing, and dancing. Non-lean-build sports included basketball, netball, soccer, tennis, hockey, volleyball, squash, Australian football, and trampoline. These classifications were based on Beals and Hill (2006).

[a]Training/competition pertaining only to the participants' predominant sport. [b]Reporting at least 2 of the following behaviors on a weekly basis: fasting, self-induced vomiting, use of laxative, use of diuretics. [c]Reporting missing periods for at least 3 months. A note regarding questions on amenorrhea was included in the survey so that the participants would disregard situations when they missed periods intentionally by taking the oral contraceptive pill or because of pregnancy.

*$p < .005$. **$p < .0005$ for lean-build vs. non-lean-build sports.

> Exercising regularly can cost a lot of energy. Some women can become low in energy if their energy intake is similar to sedentary women and therefore does not compensate for the energy cost of training. What suggests to you that an active woman could be energy deficient?

The respondents then had to tick all that applied. Approximately one fourth of them (24%) correctly identified rapid weight loss, absent menses, and stress fractures as potential signs of energy deficiency. Fifty-four percent indicated that amenorrhea could suggest that an active woman might be energy deficient (68% in lean-build sports vs. 39% in non-lean-build sports, $p < .0005$). Participants who reported a history of menstrual dysfunction were more likely to correctly identify the signs of energy deficiency ($p < .0005$). Only half the respondents indicated that a rapid weight loss (2–3 kg) could suggest an athlete's state of energy insufficiency.

Approximately one third of the population (35%) considered irregular periods "normal" for active females, particularly those who reported a history of menstrual dysfunction (51% vs. only 27% of those with no reported history of menstrual dysfunction, $p = .003$). Regardless of type of sport (lean-build vs. non-lean-build), 1 in 2 athletes competing at the international level considered amenorrhea normal in active females. This proportion decreased from the international level to the national level (36%), state level (33%), and local level (29%), a decrease observed in both lean-build and non-lean-build sports.

Table 2 presents reasons given by participants about why they believed missing three consecutive periods may be normal or abnormal. The proportion of participants who provided each category of response is also presented in Table 2. This analysis does not necessarily reflect all participants' opinions because 34% of them did not provide a reason for their belief that missing three consecutive periods could be normal or abnormal. The participants' answers were categorized according to what was conveyed as the predominant theme or reason in their response (Table 2). Some participants completed their response and gave a secondary reason. For example, 3 athletes reported that amenorrhea is not normal because it may indicate low iron levels or anemia (primary reason), but another 7 athletes also mentioned low iron levels or anemia as a secondary reason. The list of secondary reasons is not provided for the sake of clarity.

Our qualitative data also highlighted some beliefs or feelings among the athletic female population: Amenorrhea is a natural side effect of heavy training, amenorrhea does not affect overall health, and low iron levels are the main reason for the cessation of menstrual cycles. These beliefs are well illustrated by some of the participants' answers when asked "Do you believe missing periods over at least 3 months has any effects on overall health and why?": "I don't get my period and it has no effect on my overall health" (Subject 25), "I'd assume it was because I had lost weight (and would therefore be happy!)" (Subject 52), "I view it as a success that I am losing weight and below a healthy weight. I am a long-distance runner and fight to stay at a low weight" (Subject 54), "I haven't seen any effects, I like it!" (Subject 107), and "If you miss it for that long then I think it indicates that something is wrong with your body, unless you're in heavy training in which case sometimes it happens" (Subject 57). All the quoted participants were among those who would take no action if they missed three consecutive periods.

Fifty-four percent of the athletes correctly identified menstrual dysfunction as a risk factor for weak bones (63% of athletes in lean-build sports vs. 46% of athletes in non-lean-build sports, $p < .05$). Best scores were found in triathletes (13/13, 100%) and athletes/runners (25/34, 74%), whereas only 27% of cyclists (3/11) correctly identified the link between menstrual dysfunction and poor bone health. The participants showed a better capacity to correctly identify other risk factors for weak bones, such as low calcium intake (98% answered correctly), family history of osteoporosis (94%), or anorexia nervosa (81%; Figure 1).

The vast majority of the respondents (88%) indicated they would take action if they missed three consecutive menstrual periods unintentionally. The following factors were associated with taking action in the presence of amenorrhea: participation in non-lean-build sports (vs. lean-build sports), no history of menstrual dysfunction (vs. history of menstrual dysfunction), and no history of stress fracture (vs. history of stress fracture; $p < .005$). Among the 13 participants presenting with these three factors, 8 (62%) would do nothing if faced with amenorrhea again. Common behaviors reported by the participants who would take action if experiencing amenorrhea included talking to their general practitioner (89%), their mother (28%), another health professional (18%), a teammate (11%), or their coach (1.3%; these categories were not exclusive of each other).

Discussion

This study investigated the knowledge, attitudes, and behaviors of Australian female exercisers toward the female athlete triad. The study found that a significant proportion of adult female exercisers are unaware of the link between energy deficiency and menstrual dysfunction, as well as the detrimental effects of menstrual dysfunction on bone health. Participants who engaged in lean-build sports were more likely to identify amenorrhea as a risk factor for poor bone health than those engaged in non-lean-build sports; however, they were less likely to take action if they missed periods over a long duration.

The proportion of athletes who knew about the link between menstrual dysfunction and poor bone health (54%) was within the range of results reported previously in female athletes (30–40% by Simpson et al., 1998 and 72% by Turner & Bass, 2001). Discrepancies between studies could be explained partly by different phrasing used in their surveys. We noted that athletes who reported a history of stress fracture were not better informed about the fact that amenorrhea is a risk factor for poor bone health. These athletes were also less likely to take action

Table 2 Responses Provided by Participants as to Why They Believed That Missing 3 Consecutive Periods Was Normal or Not

Response and reason	*n*	%
Missing 3 consecutive periods is not normal because it is related to . . .		
Health issues (unsure/nonspecific/incorrect)	32	17.8
Negative effects on bone health	16	8.9
Reduced fertility/reproductive system abnormalities	10	5.5
Hormonal imbalances	6	3.3
Low body fat/underweight	6	3.3
Excessive training	3	1.6
Stress	5	2.8
Iron levels/anemia	3	1.6
No reason given	22	12.2
Missing 3 consecutive periods is normal because . . .		
Common/normal for female athletes to miss periods	5	2.8
No noticeable issues/side effects on health	12	6.7
Due to contraceptives	1	0.6
Doctor said it is okay	1	0.6
No reason given	16	8.9
Unsure whether missing 3 consecutive periods is normal		
Unsure about potential effects on health	19	10.6
due to poor knowledge on the issue	6	3.3
never had absence of menses *or* due to contraceptives *or* polycystic ovary syndrome	5	2.8
No reason given	23	12.8
Participants included in the qualitative analysis	175	97.2
Participants excluded from this analysis[a]	5	2.8
Total	180	100

[a]Five cases were excluded from the analysis because their answer to the question "Do you think there is any effect of missing 3 consecutive periods?" (yes/no) was in contradiction with the justification they gave to support their answer. For example, one participant who responded "No" effect of missing three consecutive periods gave the following justification, which indicates she believes there are detrimental effects: "It is an indicator that there is something out of balance with your body—it could be stress or a physical issue such as low iron or low body weight."

if faced with amenorrhea, despite a large body of evidence showing that amenorrhea is a risk factor for stress fracture (Bennell, Matheson, Meeuwisse, & Brukner, 1999; Lappe et al., 2008). Such behavior was unexpected considering that those who had reported a diagnosed stress fracture would likely have visited a doctor, who presumably would have investigated menstrual history.

By far, most respondents reported they would take action if they missed three consecutive periods. However, a small group of athletes engaged in lean-build sports and reporting a history of menstrual dysfunction and stress fracture seemed to be at risk for not taking appropriate action if faced with amenorrhea, despite showing better knowledge that it could indicate energy deficiency. This observation suggests that knowledge does not necessarily transfer into appropriate behavior, which supports previous findings (Chapman et al., 1997; Raymond-Barker et al., 2007; Sedlak, Doheny, & Jones, 2000; Wiita & Stombaugh, 1996). This implies that providing theory-based nutrition education alone may not be sufficient to prevent the female athlete triad. Two major motivational factors could significantly influence the learning and application of sound nutrition principles in female athletes: (a) level of performance and weight control (Chapman et al., 1997; Simpson et al., 1998) and (b) stronger perceived pressure to achieve a lean body shape in female athletes in lean-build sports than in males, normal-build athletes, and nonathletes (Byrne & McLean, 2002). These two factors should be considered when designing education programs because they may have a significant influence

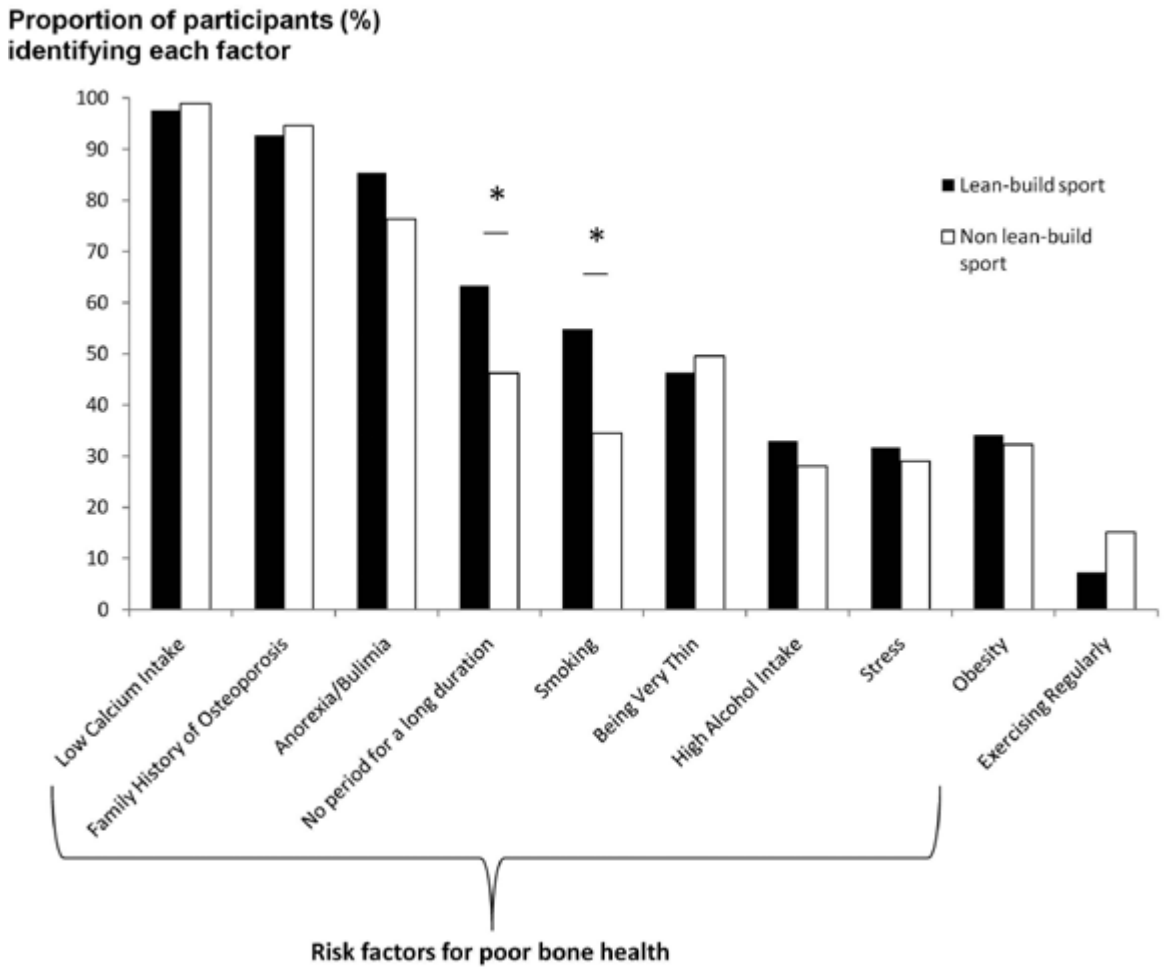

Figure 1 — Capacity to identify risk factors for having weak bones in female exercisers depending on type of sport. *$p < .05$ for lean-build sport vs. non-lean-build sport. Lean-build sports: running/athletics, cycling, triathlon, swimming, rowing and dancing. Non-lean-build sports: basketball, netball, soccer, tennis, hockey, volleyball, squash, Australian football, and trampoline. Participants were asked, "Please tick the factors from the following list that you think would increase the risk of having weak bones." Among the factors in the list (shown on the *x* axis), the participants could tick as many factors as they wanted. Obesity and exercising regularly were not risk factors for poor bone health, so ticking these factors was scored as an incorrect answer.

on athletes' food choices. With over one third of female exercisers still believing that irregular periods are normal in athletes, greater education directed toward athletes, coaches, parents, and health care professionals is needed on the detrimental effect of menstrual dysfunction on bone health. Coaches, parents, and teammates, along with magazines, were found to be the top four sources of nutrition information in cross-country runners (Zawila et al., 2003). We found that 7% of participants believed amenorrhea had no effect on health because they did not notice any side effects. This may indicate that bone health is not a concern or that these female athletes are not informed about the adverse effects of menstrual dysfunction. Therefore, education programs should explain that osteoporosis is a silent disease, often remaining undetected until the first osteoporotic fracture occurs (unless a DXA scan is performed before the fracture). Lack of concern by young sporting women about their risk of osteoporosis has already been shown (Turner & Bass, 2001). This is likely to explain the significant proportion of female athletes not taking preventive measures that can benefit health in the long term (Anderson & Auld, 1996; Kasper, Peterson, Allegrante, Galsworthy, & Gutin, 1994; Turner & Bass, 2001). Lean-build sports might present more risk factors for developing the female athlete triad than non-lean-build sports, such as greater perceived pressure to be thin and a demonstrated higher prevalence of eating disorders (Beals & Hill, 2006; Byrne & McLean, 2002), although in our study it was difficult to discriminate between the effects of the specific sport, the training volume, and level of competition, as the last two parameters were higher in lean-build sports (see Table 1).

A limitation of this study was that the survey methodology implies that results are solely based on self-report. For example, athletes have been shown to overreport incidence of stress fractures (Oyen, Torstveit,

& Sundgot-Borgen, 2009), and this might have occurred in our sample. In addition, the participants needed to be told what the survey was about for ethical purposes. The presentation of the topic was kept to its minimum because the whole point of the survey was to investigate knowledge about the female athlete triad. However, as with any survey or questionnaire, the subjects may have answered according to what they think is "correct" to think or do, rather than what they truly think or do. It is extremely hard to control for this bias, which may have affected our findings. Participants were not randomly selected, and those who filled out the survey may have had a particular interest in the topic. Therefore, athletes' knowledge might actually be poorer than observed. Recruitment in this study was also limited to adults, and further investigations are needed in adolescent athletes, a group who also display components of the female athlete triad (Chapman et al., 1997; Nichols et al., 2006). Thorough investigations in gym-based exercisers, who may be at risk for disordered eating (Ball, Andajani-Sutjahjo, & Crawford, 2003), could not be conducted due to the small sample size in this subgroup. Beyond the differences between lean-build and non-lean-build athletes' knowledge on the female athlete triad, it also appeared that there were differences between individual sports within the same category. Significant differences were hard to find due to relatively low sample sizes of individual sports, so they must be considered with caution. However, it would appear incorrect to assume that female athletes in all lean-build sports have the same level of knowledge or would behave the same in the context of the female athlete triad as those in non-lean-build sports. Future studies could address gaps in current research by investigating knowledge, attitudes, and behaviors toward the female athlete triad in clinicians, coaches, and parents since they are key elements in preventing the female athlete triad. Initiatives have been taken in the United States. For example, the Female Athlete Triad Coalition has a Web site that includes a section with educational materials, mainly videos, slide shows, and brochures (www.femaleathletetriad.org). This coalition is one of the most active organizations aiming to prevent the female athlete triad by providing information for athletes, coaches, parents, and health professionals. Similar initiatives in other countries would be beneficial. Furthermore, no study has ever compared the efficacy of different education programs to prevent or treat the female athlete triad. Intervention programs based on our results are required in large samples to test the efficacy of various strategies to prevent the female athlete triad.

Conclusions

Despite relatively good knowledge of several risk factors for poor bone health (e.g., low calcium intake), a significant proportion of adult female exercisers in Australia are not aware of the detrimental impact of amenorrhea on bone health and still believe that irregular periods are a normal consequence of intense training. Knowledge of the female athlete triad and its components does not necessarily translate into appropriate behaviors in the presence of amenorrhea, therefore putting bone health at risk. This is a concern because amenorrhea is one of the first overt signs that an active female might be energy deficient (in the absence of pregnancy or medical conditions that are associated with amenorrhea). These findings indicate that education programs and further research on the female athlete triad are required to inform female athletes about the condition, its prevention, and treatment options, while taking into account their concerns about weight control and performance.

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