

## Article

# Low Energy Availability and Eating Disorders Risk: A Comparison between Elite Female Adolescent Athletes and Ballet Dancers

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**Abstract:** This study examined the risk of low energy availability (LEA) and eating disorders among elite adolescent female athletes from a mixed-sport cohort and ballet dancers in Singapore, where the accelerated biological needs of adolescent growth and maturation overlap with the pursuit of sport/ballet excellence and high-stakes academic testing. All of these are competing demands for adequate fuelling and seeking timely treatment, which consequently affect the risk of LEA. Eighty-nine participants (41 athletes, 48 dancers; age 16.00 [3.00] years old) were screened for the risk of LEA and eating disorders using the Low Energy Availability in Females Questionnaire (LEAF-Q) and Brief Eating Disorder in Athletes Questionnaire (BEDA-Q), respectively. The main effects of athlete/ballet status and age ( $\leq 15$  years old versus 15.1 years–18 years old) on LEAF-Q and BEDA-Q scores was determined via Spearman's correlation coefficient and linear regression analyses. The Mann–Whitney U test and Fisher's exact test were used to compare the groups for the risk of LEA and ED. We observed that adolescent athletes and ballet dancers had a similar prevalence of being at risk of LEA (61.98% versus 54.17%, respectively,  $p = 0.529$ ), with the risk of eating disorders absent in most of them. It appeared that the risk of LEA is likely of an unintentional nature in this study as the risk of ED was absent in 90.2% of the adolescent athletes/ballet dancers that were at risk of LEA. The age of the participants was significantly correlated with the risk of LEA, while the number of training hours was negatively correlated with the same factor. Age was also found to be negatively correlated with the number of training hours. The findings suggest that the risk of LEA in Singapore youth athletes and dancers are multifaceted, involving factors such as type of activity, age, and training hours. Targeted and tailored interventions and programmes are thus needed to promote adequate energy availability for optimal physical and psychological growth in sport and dance.



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## 1. Introduction

Low energy availability (LEA) occurs when either the energy intake is too low or the energy output through training is too high, leading to an insufficient amount of energy left to maintain normal physiological functions such as bone health, cardiovascular health, immune function, and menstrual function in female athletes [1–6]. Both athletes and ballet dancers are driven by strong internal and external pressure to achieve optimal performance [6]. The screening of LEA risk through self-reported questionnaires in adult populations has revealed rates of 57% among ballet dancers [7] and 55% within a mixed cohort of athletes [8,9]. Common scenarios in sports and ballet that may increase the risk of underfuelling and LEA include attempts to improve the power-to-weight ratio, desire for excessive leanness, or excessive emphasis on a lower body mass, and the pursuit of

an optimal body type or physique [6]. While there has been an abundance of research on adult female athletes and performing artists such as endurance runners [1], team sport athletes [8,10], gymnasts [11–13], and ballet dancers [7,14], less is known about the adolescent population, despite the heightened risk of LEA during this critical period of physical development and maturation [14–19]. Studies that have investigated the risk of LEA in adolescents (<18 years old) reported a prevalence of 50% in netballers [20] and up to 72% in dancers [12,17]. These findings suggest that the risk of LEA in adolescents is either comparable to or even higher than that in adults, with ballet dancers facing particularly elevated risks. Adolescents present unique challenges in estimating energy needs due to the physiological demands of growth, maturation, and training. These challenges are compounded by less sporting/dance experience and school commitments, which can lead to an underestimation of energy requirements, poorer food choices, body image concerns, and consequently, an increased risk of LEA in this population [14–19].

Levels of experience have been shown to influence food choices and confidence in making food-related decisions [21,22]. With adolescents typically having lower levels of experience, their food choices and confidence in making dietary decisions may be compromised, especially during periods of increased training volumes where dietary intake needs to be adjusted appropriately and may be difficult for an adolescent athlete or ballet dancer. Moreover, due to academic commitments, convenience often takes precedence in dietary choices, with similar trends shown among college students and adolescents, who rate convenience as a priority [23,24]. Furthermore, the onset of pubertal changes in body composition can heighten the susceptibility to societal pressures regarding body image and performance standards, further exacerbating vulnerability to LEA and eating disorders (EDs), particularly among older adolescents [25–28].

LEA occurs as a continuum, where effects can be benign (adaptable LEA) or potentially detrimental to health and/or performance (problematic LEA) [6,29]. It is the main aetiological factor of the female athlete triad (the Triad), which represents the relationship between three related components—LEA, menstrual dysfunction, and low bone mineral density [30]. LEA, however, can lead to impaired functions in other areas including, but not limited to, cardiovascular health and immune function. This led to the definition of a syndrome known as “Relative Energy Deficiency in Sport (REDs)” by the International Olympic Committee (IOC) in 2014 and has since been updated twice in 2018 and 2023 [6,31]. Reasons for LEA may range from unintentional LEA due to a mismatch between dietary intake and training output to intentional LEA with disordered eating (DE) and eating disorders (ED) [2,4]. While LEA has been widely associated with disordered eating as the latter can lead to underfuelling [32], both conditions are aetiologically different and LEA can exist without DE/ED [31].

Early detection through screening has been recommended by the IOC in its clinical assessment tool as the first step to minimise the incidence of LEA and progression to benign and problematic LEA [6]. The process includes the identification of athletes presenting with menstrual dysfunction, recurrent injuries and illness, weight loss, mood changes, lack of normal growth, or signs of DE/ED [2]. However, the assessment of REDs risk and severity is challenging due to the subtle symptomology and the time taken for various LEA indicators (signs and symptoms) to manifest as these indicators do not occur overnight [2,6,29]. The process of screening and REDs assessment can be further complicated by the poor knowledge of the condition and societal/cultural stigma surrounding the menstrual cycle in females as menstrual irregularity is one of the key clinical symptoms of LEA.

Knowledge about LEA has been observed to be poor amongst adolescent athletes and performing artists. In a survey of 712 adolescent and young adult runners, dancers and figure skaters, 16% of young adults had a high level of knowledge of the Triad as compared to 4.5% of adolescents (<17 years old;  $p < 0.001$ ), with only 8% of dancers having heard of the Triad [12]. In a survey of 170 mixed-sport cohort study of high school athletes in the western United States, only nine athletes had heard of the Triad and none could correctly list the Triad components [33]. In adult ballet dancers, only 29% and 37% had

heard of REDs and LEA, respectively, while 90% were aware of DE [7]. Though no research is available for Singapore's context, based on prevailing trends, it is likely that knowledge about LEA among local adolescent athletes and ballet dancers will be low, making them susceptible to an increased risk of LEA.

In Singapore, stigma surrounding the menstrual cycle has been observed to be pervasive and help-seeking behaviour in adolescents surrounding the menstrual cycle has been observed to be poor. When surveying the barriers and facilitators for communication related to the menstrual cycle, the common theme among the adolescent athletes ( $n = 84$ ) in Singapore was viewing the menstrual cycle as an "uncommon topic deemed as dirty" or a personal topic that should be kept private [34]. Only 6% of 5561 adolescent girls in Singapore reported seeking medical help for dysmenorrhea (i.e., painful menstruation) [35], while 41% out of 1092 girls in the same study indicated that they would prefer to menstruate every three to four months. Together, these are concerning as female adolescent athletes have also been shown to think that the absence of menstruation is a normal response to a high level of athletic training [36,37].

The chances of adolescents in Singapore talking about menstrual disturbances and potentially seeking help for LEA is therefore likely to be decreased, which necessitates the active screening for LEA. Given the variations in how menstruation is perceived within societies, research into LEA in Singapore may yield insights that are more contextually relevant. However, research in the area of LEA in Singapore is scarce and understanding the prevalence of LEA risk is essential to creating awareness, which allows at-risk adolescents to be treated in a timely fashion and supports conversations about the condition.

Therefore, the present study aimed to—(i) compare the prevalence of LEA risk in an adolescent mixed-sport cohort versus ballet dancers and (ii) explore the relationship between age and training hours on LEA risk. The hypotheses of this study are that (i) a greater proportion of adolescent ballet dancers will be considered to be of "at risk of LEA" and "at risk of ED" as compared to adolescent athletes and (ii) a lower proportion of younger adolescents (15 years and below) will be considered to be of "at risk of LEA" and "at risk of ED" as compared to the older adolescents (15.1–18 years old).

## 2. Materials and Methods

### 2.1. Study Population and Design

Female athletes from national youth development squads of non-aesthetic/endurance sports and ballet students from a national pre-tertiary specialised arts school, aged 13–18 years old, were screened for the risk of LEA and ED using two questionnaires: the Low Energy Availability in Females Questionnaire (LEAF-Q) [38] and the Brief Eating Disorder in Athletes Questionnaire (BEDA-Q) [39], respectively. The questionnaires were completed prior to the athletes' and ballet dancers' participation in sport science/nutrition workshops between 2019 and 2021. All athletes competed minimally at an international level, and are considered Tier 2 athletes in consideration of the performance rankings according to the Participant Classification Framework by McKay et al. (2021) [40].

Parent/guardian informed consent was obtained for the athletes who provided the participant assent. The athletes came from a convenient sample of five sports—badminton, kayak sprint, taekwondo, netball, and water polo. Ethical approval for this study was obtained from the BLINDED FOR PEER-REVIEW Institutional Review Board BLINDED FOR PEER-REVIEW).

The LEAF-Q is a self-reported 25-item questionnaire by Melin et al. (2014) that is validated in female athletes with acceptable sensitivity and specificity in identifying female athletes' risk for the Female Athlete Triad [38]. It contains questions that assess three subcategories of REDs indicators (injuries, gastrointestinal symptoms, and reproductive/menstrual function) and each question is given a numerical score. A score of  $\geq 8$  out of 49 indicates a risk of LEA by the original authors [38]. Sufficient evidence has been reported in non-endurance elite and pre-elite athletes since its development and validation in endurance female athletes to support the use of LEAF-Q for mass screening or to rule

out the risk of conditions related to LEA across other sports [41]. The LEAF-Q has been shown to have a high negative predictive values [41]. In line with this, participants in this study were considered at “low LEA risk” with a LEAF-Q score <8. Rogers et al. (2021) recommended against classifying a LEAF-Q score of  $\geq 8$  as a “high LEA risk” due to the low positive predictive values in their study [38]; however, a LEAF-Q score of  $\geq 8$  was considered as “at risk of LEA” in this study as recommended by the original authors [38]. Additionally, participants were considered to have the corresponding REDs indicator if their subcategory scores were as follows:  $\geq 2$  for gastrointestinal symptoms;  $\geq 2$  for injuries; and  $\geq 4$  for menstrual dysfunction [38].

The BEDA-Q is a 9-item self-reported questionnaire that screens for athletes who are at risk of ED by using a weighted equation score, where a score of  $\geq 0.27$  is classified to be at risk of an eating disorder (at risk of ED) [39,42]. It has been used in combination with LEAF-Q for greater insights into eating behaviours that may cause intentional LEA [43].

## 2.2. Statistical Analyses

A minimum sample size of  $n = 38$  per group determined to give sufficient statistical power at an effect size of  $d = 0.50$  and  $\alpha = 0.0544$  [44]. Results are presented as median and IQR for non-parametric data. Analyses were undertaken using IBM SPSS Statistics Version 21.0 (IBM Corporation, New York, NY, USA, 2012). The degree of association between the LEAF-Q score, BEDA-Q score, and other variables was assessed by Spearman’s correlation coefficient. Linear regression analyses were also performed to examine the association between age, training hours, and LEA risk among youth athletes. Participants were divided into two groups based on their LEAF-Q score ( $\geq 8$  [at risk of LEA] and  $< 8$  [low risk of LEA]) [37] and age ( $\leq 15$  years old [younger adolescents] and 15.1–18 years old [older adolescents]). The Mann–Whitney U test and Fisher’s Exact test were used to compare the groups for the risk of LEA and ED. Statistical significance was accepted at  $p < 0.05$  (two-tailed) for all statistical tests and inferences.

## 3. Results

### 3.1. Participants Information

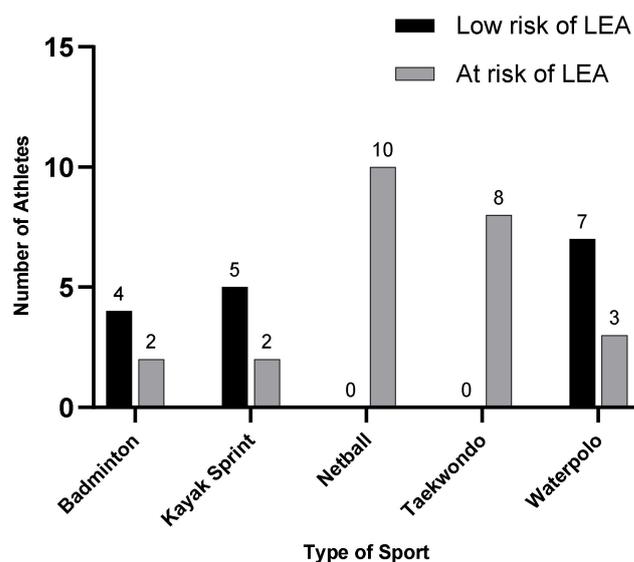
Parental/guardian informed consent and participant assent were obtained for a total of 106 youth athletes and ballet students, who completed the questionnaires with a response rate of 93%. Out of the participants who completed the questionnaires ( $n = 99$ ), seven were pre-menarcheal and three were on hormonal contraceptives for the regulation of menses. These 10 participants were excluded from the analysis, leading to a final sample of 41 athletes and 48 ballet students. The distribution by sport was as follows: badminton ( $n = 6$ ), kayak sprint ( $n = 7$ ), netball ( $n = 10$ ), taekwondo ( $n = 8$ ), and water polo ( $n = 10$ ). The median [IQR] age of the participants was 16.00 [3.00] (Table 1). A total of 51 participants were considered “at risk LEA risk” (57.3%) and seven participants were highlighted as “at risk of ED” (7.9%). Out of those identified to be at risk of LEA, 90.2% ( $n = 46$ ) were screened to be at low risk of ED.

**Table 1.** Participant characteristics (mean  $\pm$  SD) according to athlete/ballet category and age.

Parameter	Age at Time of Survey, Years	Height, cm	Weight, kg	Body Mass Index, kg/m <sup>2</sup>	Training Hours, Hours/Week	LEAF-Q	BEDA-Q
Athlete/ballet							
Athlete ( $n = 41$ ), median [IQR]	17.00 [2.00]	161.00 [3.00]	53.60 [5.05]	20.45 [1.31]	16.00 [7.00]	10.00 [5.50]	−1.18 [0.86]
Ballet ( $n = 49$ ), median [IQR]	14.00 [0.00]	159.00 [4.00]	46.45 [3.45]	18.39 [1.29]	12.00 [3.19]	8.00 [3.00]	−0.88 [0.75]
Mann–Whitney U	593.50	721.00	384.50	403.00	821.00	778.50	1133.50
<i>p</i> -value	<0.001	0.030	<0.001	<0.001	0.179	0.090	0.217
Age							
13–15 years old ( $n = 42$ ), median [IQR]	14.00 [0.25]	159.00 [4.00]	47.00 [4.13]	18.57 [1.35]	14.50 [3.63]	7.00 [3.00]	−0.88 [1.82]
15.1–18 years old ( $n = 47$ ), median [IQR]	17.00 [0.00]	163.00 [5.00]	52.00 [4.00]	19.99 [1.44]	10.00 [2.50]	10.00 [4.00]	−0.88 [0.75]
Mann–Whitney U	1974.00	1408.50	1512.00	1372.00	647.50	1240.50	1002.00
<i>p</i> -value	<0.001	<0.001	<0.001	0.002	0.005	0.037	0.902

### 3.2. Risk of LEA/ED in Athletes and Ballet Dancers

There was no significant difference between the training hours, LEAF-Q scores and BEDA-Q scores between the athletes and dancers, despite the athletes having a higher BMI (median [IQR] = 20.45 [1.31] versus 18.39 [1.29],  $p < 0.01$ ). There was a greater proportion of athletes (61.98%,  $n = 25$ ) being considered to be “at risk of LEA” as compared to ballet dancers ( $n = 25$  [61.98%] versus  $n = 26$  [54.17%],  $p = 0.529$ ). However, fewer athletes (39.02%,  $n = 16$ ) were considered at “low LEA risk” as compared to dancers (45.83%,  $n = 22$ ), with no athletes from netball and taekwondo considered to be at a “low LEA risk” (Figure 1).



**Figure 1.** Risk of LEA across five sports in a mixed-sport cohort. Note: LEA = low energy availability; LEAF-Q = Low Energy Availability in Females Questionnaire. Risk of LEA was assessed based on the LEAF-Q scores:  $\geq 8$  [at risk of LEA] and  $< 8$  [low risk of LEA].

Seven participants were considered “at risk of ED” (7.87%), with the majority being ballet dancers ( $n = 6$ ) and the remaining athlete was from taekwondo. Out of these seven individuals, five were considered “at risk of LEA” (four were dancers, one was from taekwondo).

### 3.3. Risk of LEA/ED in Younger versus Older Adolescents

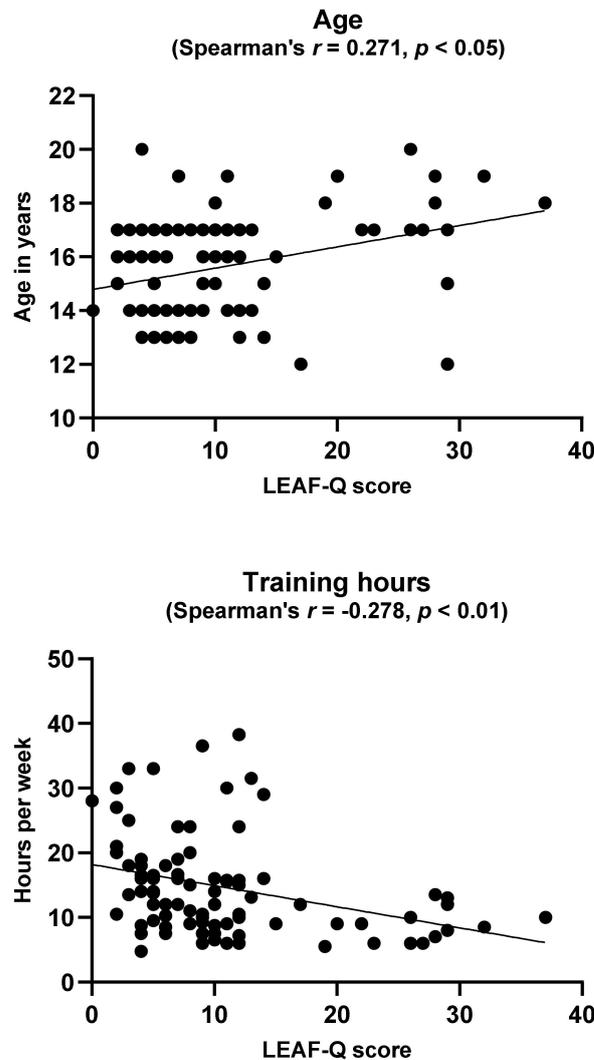
Participants aged 15.1–18 years old had a significantly higher LEAF-Q score than the younger participants (Table 1, median [IQR] = 7.00 [3.00] versus 10.00 [4.00], respectively,  $p < 0.05$ ). This was despite the older participants having lower training hours than the younger participants aged 15 years old and below (Table 1, median [IQR] = 14.50 [3.63] versus 10.00 [2.50],  $p < 0.01$ ). BMI was higher in the older participants while BEDA-Q showed no significant differences between the two age groups. Amongst the dancers classified as at “low LEA risk”, the majority (63.6%) of dancers were 15 years old or younger (Table 2). In contrast, an equal proportion of athletes classified as “low LEA risk” were in both age groups (Table 2).

Age demonstrated a positive correlation with LEAF-Q scores ( $r(87) = 0.271$ ,  $p < 0.05$ ), which showed that, as age increased, the risk of low energy availability also increased. Conversely, training hours exhibited a negative correlation with age ( $r(87) = -0.278$ ,  $p < 0.01$ ), indicating that as age increased, the training hours decreased. Training hours also showed a negative correlation with LEAF-Q scores ( $r(87) = -0.388$ ,  $p < 0.01$ ). This demonstrating that as the training hours decreased, the risk of low energy availability increased. The results of these correlations are presented in Figure 2. LEAF-Q scores showed no significant association with BEDA-Q scores.

**Table 2.** Chi-square results for age and risk of low energy availability (LEA) and eating disorders (ED).

Parameter	Risk of LEA <sup>a</sup>		Risk of ED <sup>b</sup>	
	Low Risk	At Risk	Low Risk	At Risk
<i>Athlete</i>				
13–15 years old (n = 14)	8	6	14	0
15.1–18 years old (n = 27)	8	19	26	1
Pearson $\chi^2$				
- $\chi^2$ statistic	2.933			
- <i>p</i> -value (two-sided)	0.087			
Fisher’s exact test (two-sided)	0.105		1	
<i>Ballet Dancer</i>				
13–15 years old (n = 28)	14	14	23	5
15.1–18 years old (n = 20)	8	12	19	1
Pearson $\chi^2$				
- $\chi^2$ statistic	0.47			
- <i>p</i> -value (two-sided)	0.493			
Fisher’s exact test (two-sided)	0.565		0.379	

Note: LEA = low energy availability; LEAF-Q = Low Energy Availability in Females Questionnaire. <sup>a</sup> Risk of LEA assessed using the Low Energy Availability in Females Questionnaire (LEAF-Q): a LEAF-Q score <8 is classified as “low risk” and a score of ≥8 is classified as “at risk”. <sup>b</sup> Risk of LEA assessed using the Brief Eating Disorder in Athletes Questionnaire (BEDA-Q): a BEDA-Q score <0.27 is classified as “low risk” and a score of ≥0.27 is classified as “at risk”.



**Figure 2.** The degree of association indicated by the black line between the LEAF-Q score and age (**top**), as well as between LEAF-Q score and training hours (**bottom**) in adolescent athletes/ballet dancers (n = 89). Note: LEAF-Q = Low Energy Availability in Females Questionnaire.

Results of the multiple linear regression indicated that there was a collective significant effect between the age, training hours and LEAF-Q scores, ( $F(2, 86) = 9.476, p < 0.001, R^2 = 0.181$ ). The individual predictors were examined further and indicated that age ( $t(87) = -2.673, p = 0.009$ ) and training hours ( $t(87) = 2.670, p = 0.009$ ) were significant predictors in the model. Adding BMI or whether they were an athlete/ballet dancer did not significantly change the model fit.

#### 4. Discussion

The objectives of this study were to compare the prevalence of LEA risk among high-performance female adolescents involved in sports versus ballet and explore the relationship between age and training hours on LEA risk in Singapore. Contrary to existing literature [11,42,45,46] and our hypothesis, we observed that adolescent athletes and ballet dancers had a similar prevalence of being at risk of LEA. It appeared that the risk of LEA is likely of an unintentional nature in this study, as the risk of ED was absent in most of the adolescent athletes/ballet dancers that were at risk of LEA. Our study also revealed interesting trends in LEA risk and training hours in relation to age, where the older youths in this study were at higher LEA risk as hypothesised, but this occurred despite having lower training hours. These observations highlight several important considerations and shed light on the unique challenges faced by Singaporean youth athletes and ballet dancers in maintaining adequate energy availability, including the possible influence of factors like Singapore's emphasis on studies and academic success in the later years of adolescence from 16 to 18 years old.

The primary observation of this study was a positive trend between the age and LEA risk, with LEA risk increasing as the age increased. This came alongside a decreasing trend in training hours, which suggests that among maturing youth female athletes and ballet dancers, the different risk stratification of LEA may occur. The risk of LEA may increase in older youths and common factors include growth spurts in the later adolescent years, increases in training volume/load [47]. Another plausible explanation is the time taken for LEA indicators to appear, which may take years and appear only in the latter years of adolescence [2,6,19]. However, the findings of this study appear to contrast current literature where training hours typically increase with age after 13 years of age [48–53]. A plausible explanation may lie in the unique influence of the education system in Singapore, where academic success is emphasized.

Youth athletes and ballet dancers in this study who reported fewer training hours were aged between 16 and 18 years old, coinciding with the period when many students prepare for major national examinations. This reduction in training hours likely reflects a shift towards increased academic focus in anticipation of these examinations, as the juggling of sport and academic demands is known to impose time management pressures that impact food choices and adequate fuelling [54,55]. Notably, time constraints have been identified as a primary barrier to adhering to sport-specific nutritional guidelines, potentially influencing athletes' risk of LEA, given the well-established role of time and convenience in adolescent food choices [14–19]. Coupled with limited sporting or dance experience, this can lead to underestimated energy requirements, suboptimal dietary choices, and heightened risk of LEA within this population.

The physiological demands of growth and maturation, coupled with the increased academic emphasis during the critical years, appear to place the older youth athletes and ballet dancers at a higher LEA risk in this study as observed, despite decreased training hours. To that end, it is crucial for athlete/dancer education to be prioritised in the youth sport/dance environments, including topics such as fuelling for the demands of the sport, food skills, and time management as a student-athlete/ballet dancer. Furthermore, as the menstrual cycle can be used as a vital sign in girls and adolescents [56], it would be beneficial for adolescent female athletes/dancers (and their parents) to be educated on what constitutes a normal menstrual cycle during the initial menarcheal years. Indeed, LEA is one of the main aetiologies of menstrual cycle irregularities among female athletes [6]

and being able to identify abnormal bleeding patterns can help facilitate the identification of LEA or other underlying medical conditions. Considering the pervasive menstrual taboo among adolescent female athletes in Singapore [34], it is perhaps sensible to focus efforts on addressing the menstrual stigma by raising awareness and advancing menstrual health literacy.

The investigation of LEA risk through self-reported questionnaires in adult populations has revealed rates of 57% among ballet dancers [7] and 55% within a mixed cohort of athletes [8]. Our study findings align with these statistics, as over 50% of adolescent athletes and ballet dancers were identified as being at risk of LEA. These results imply that moderating factors affecting LEA risk may track from adolescence into adulthood, which makes it important to target the adolescent athletes/ballets for the early prevention and intervention efforts to mitigate long-term health and performance consequences. The risk of ED was 7.87% in this study using the BEDA-Q. The prevalence of ED risk is consistent with existing research findings in athletes [46], which observed a wide range of ED prevalence (6–45%), but was lower than that in ballet dancers [45], who reported an ED prevalence of 16.45% in their meta-analysis. The occurrence of LEA risk observed in this study is likely to be unintentional (e.g., due to a mismatch between dietary intake and training output), rather than intentional (i.e., due to an eating disorder) [6] as most of the subjects screened to be at risk of LEA were not identified to be at risk of ED. Together, these results further support the importance of equipping youth athletes/dancers and adults in their environments (e.g., parents, coaches, teachers) with the necessary knowledge (e.g., LEA awareness) and skills (e.g., how to fuel appropriately better match the dietary intake to energy expenditure in a cost-effective and convenient manner).

There was also an absence of association between LEAF-Q and BEDA-Q score, further supporting the notion that LEA and ED are two different conditions and can exist independently of the other condition. No significant difference in BMI was observed between the participants at low risk of LEA versus those at risk of LEA and this was further supported by an absence of the significant association between LEAF-Q score and BMI in this study. Existing evidence that has looked at pre-elite athletes or dancers have been mainly conducted in adults [7,8], while studies that included youth athletes did not mention associations with BMI [10,12]. The results of this study reinforce the IOC's recommendation for early screening [6]. In particular, both LEA and ED should be screened separately in youth athletes/dancers, especially as they approach pubertal years, when the screening of LEA should not be limited to only sports/dance genres where a low BMI is more prevalent (i.e., those that emphasise leanness/aesthetics).

Our study revealed interesting variations in LEA risk among different sports, with netball and taekwondo athletes exhibiting the highest prevalence compared to water polo, badminton, and kayak athletes. An intriguing disparity between netball and female water polo athletes was observed in our study, despite both netball and female water polo athletes being team sports consisting of seven players per team and having a gameplay of high-intensity intermittent movements that require multiple sprints and quick changes of direction [57–61]. A typical netball and water polo match both comprise four quarters, each lasting 15 min and 8 min, respectively [57–61]. The sustained periods of play in netball, combining the physical demands of play, may contribute to increased energy expenditure and potentially a higher risk of low energy availability in netball athletes [57–61].

Despite the similarities in game demands between netball and female water polo, there is a notable lack of studies comparing the physiological and psychological demands between the two sports. The influence of the body image in both sports are worth examining in future studies and may explain the difference in the risk of energy availability observed in this study. While netball and female water polo have been considered “non-lean” sports [62], a preoccupation with body image has been associated with nutritional restriction in elite netball players [63]. While no netball athletes showed a high ED risk through the BEDA-Q screening tool, the observation of ballet dancers seemingly having a lower LEA risk but a persistently higher ED risk suggest that future studies that explore the perspectives in

body image and both the dance and sport environment can be useful towards creating synergistic strategies for better management of LEA and ED in youths.

Weight making, a process that is considered of competitive importance in combat sports like taekwondo, has been shown to be causative of LEA, LEA risk, and ED risk [64–66]. The findings of this study support the prevailing literature by demonstrating a higher prevalence of LEA risk among the taekwondo youth athletes and the only athlete identified as at risk of ED was from this sport. This emphasises existing calls for safe practices in weight-making for combat sports like taekwondo. Furthermore, despite the inherent differences in body compositions and physiological systems, the observed behaviours and practices related to weight management appeared to be similar across sexes [65,66], thus highlighting the need for sex-specific strategies. Coaches and practitioners working with taekwondo should be aware of the specific demands and challenges by these athletes, taking appropriate measures to optimize the energy intake, monitor weight management practices, and provide education on proper nutrition to mitigate the LEA and ED risk.

It is important to note that the findings of this study are based on a specific small sample of youth athletes and ballet dancers in Singapore and may not be generalized to other populations or countries. However, the observed disparity between the prevalence of LEA in youth athletes and ballet dancers suggests the need for tailored interventions and support systems specific to the demands of youth sports. The competitive nature of youth sports and dance, coupled with the demands of growth and maturation, and the rigorous academic curriculum in Singapore, may contribute to inadequate energy intake and a higher risk of low energy availability as the youths mature. Other limitations of this study include—(1) that the LEAF-Q and BEDA-Q are not validated on adolescents and (2) that the menstrual cycle length can go up to 45 days in adolescent girls within 3–5 years of menarche [56]. While these limitations do not affect the comparison between groups in this study, more research is warranted to screen and identify LEA in adolescents.

Future research should delve deeper into understanding the moderating factors contributing to the differential risk of low energy availability among youth athletes and ballet dancers in Singapore, such as training volume, food environment, psychological stressors, and sociocultural influences. Moreover, investigating the effectiveness of interventions targeting energy availability and nutritional support in these youths could provide insights into the development of evidence-based practices to minimize the risk of LEA and its associated health consequences.

## 5. Conclusions

In conclusion, our study highlights a notable difference in the prevalence of LEA risk between older and younger female adolescent athletes and dancers in Singapore, despite decreased training hours in the older youths. Youth athletes were also observed to have a higher proportion of individuals at risk of low energy availability. This finding underscores the need for targeted interventions, education programs, and support systems to promote adequate energy availability and prevent the occurrence of LEA in youth athletes participating in sports such as netball and taekwondo. By addressing these disparities and implementing evidence-based strategies, researchers and practitioners can work towards optimizing the health and well-being of youth athletes and ballet dancers, thereby promoting sustainable youth sport and dance development.

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