Amenorrhea and oligomenorrhea risk related to exercise training volume and intensity: Findings from 3,705 participants recruited via the STRAVA™ exercise application

Marissa N. Baranauskas[1], Jessica A. Freemas[2,3], Stephen J. Carter[2], Joanna M. Blodgett[5,6], Charles R. Pedlar[3,4,5,6], Georgie Bruinvels[3,4,5,6]

[1]Department of Human Physiology & Nutrition, University of Colorado, Colorado Springs, CO, USA

[2]Department of Kinesiology, Indiana University, Bloomington, IN, USA

[3]Orreco, Business Innovation Unit, National University of Ireland Galway, Galway, Ireland

[4]Faculty of Sport, Allied Health and Performance Sciences, St. Mary's University, Twickenham, UK

[5]Institute of Sport, Exercise and Health, Division of Surgery & Interventional Science, University College London, London, UK

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Corresponding Author

Marissa N. Baranauskas, Ph.D.

Department of Human Physiology & Nutrition

University of Colorado, Colorado Springs, CO

Phone: 440-223-7837

Email: mbaranau@uccs.edu

Abstract

The physiological underpinnings of amenorrhea/oligomenorrhea (AO) among exercising women are complex and incompletely understood. **Objectives:** To investigate associations between self-reported exercise training habits and AO among physically active women. **Design:** A cross-sectional survey was completed by 3,705 women (median age = 40 years [Quartile 1, Quartile 3: 30, 45], body mass index [BMI] = 22.1 kg/m^2 [20.5, 24.2]) representing multiple nationalities and sports via the STRAVA™ exercise application. Respondents selected the amount of time they participated in low intensity (LIT), moderate intensity (MIT), and high intensity training (HIT) per week. **Method:** Associations between weekly volumes of LIT, MIT, and HIT and AO were assessed with univariate logistic regression models, followed by models adjusted for age and BMI. **Results:** AO prevalence was 16% (n = 576/ 3,705) and was not associated with country of origin or most sport modes assessed. In adjusted models, LIT ≥ 7 h/week and MIT ≥ 6 h/week was associated with a 1.43 (95% CI:1.04 - 1.96, p = 0.03) and 1.46 (1.10 - 1.95, p = 0.01) greater risk for AO, respectively, compared to 2 to 3 h/week. Participating in LIT for ≤ 30 min/week compared to 2 to 3 h/week was associated with reduced AO risk (0.65 [95% CI: 0.44 – 0.94, p = 0.02]). HIT ≥ 5 h/week was associated with a 1.41 (1.03 - 1.92, p = 0.03) greater AO risk compared to 1 to 2 h/week. **Conclusions:** Collectively, these associations suggest that greater weekly exercise volumes, irrespective of intensity, may increase AO risk.

KEYWORDS: RED-S, female athlete triad, menstrual cycle, sports

Introduction

Menstrual cycle dysfunction, which includes the infrequency or complete absence of menses [i.e., amenorrhea and oligomenorrhea (AO)], has been estimated to affect up to 60% of women who regularly exercise compared to <11% of sedentary women.[1-3] The physiological underpinnings of AO are complex and incompletely understood, but have been attributed to low energy availability with resultant hypothalamic-pituitary-gonadal axis dysfunction and subsequent suppression of ovarian sex hormone production [4-6]. Even when energy balance is well maintained during periods of intensified physical training, there is some evidence suggesting the stress of exercise itself may increase AO risk. For example, despite demonstrating a linear increase in the frequency of menstrual cycle dysfunction with greater magnitudes of energy deficiency attained through a controlled diet and exercise intervention, Williams et al. (2015) observed 1/8 (13%) women developed oligomenorrhea in a control group where energy balance was maintained (+80 Kcal/day).[7] Lieberman et al. (2018) also found estrone-1-glucuronide, pregnanediol glucuronide, and luteinizing hormone excretion was suppressed following the initiation of a ~3 month exercise training intervention in untrained women independent of energy availability.[8] Collectively, these findings suggest the stress of habitual exercise may increase AO risk regardless of energy availability.

Current clinical guidance for reversing AO includes facilitating energy balance through reductions in exercise training and/or increasing caloric intake.[4-6] Specifically, in regards to exercise training, it is unclear whether modifications in usual volume or intensity should be prioritized in reducing AO risk and data is lacking to make such recommendations. For example, previous work relating intensified physical training to increased AO frequency have either implemented exercise programs in untrained women which necessitates an increase in usual activity volume and intensity,[7-10] or have made associations with training volume without accounting for possible differences in intensity.[11, 12] Identifying whether certain modifiable exercise training characteristics, such as volume and/or intensity, are related to AO risk would improve its management and prevention. Importantly, chronic ovarian suppression with AO is linked to a host of long-term health consequences such as low bone mineral density and cardiovascular disease.[5] Accordingly, the aims of the present investigation were to evaluate the strength of associations between AO and self-reported weekly exercise volume and intensity in a sample of over 3,000 active women representing multiple nationalities and sports who participated in the STRAVA™ x FitrWoman™ survey.

Methods

An electronic cross-sectional survey localized to 7 countries (United Kingdom, Republic of Ireland, United States of America, France, Spain, Italy, and Germany) was sent to 425,697 women aged ≥18 years who were members of a web-based exercise activity tracking service, STRAVA™. The survey was administered via email or hyperlink visible on the STRAVA™ mobile application and was available for 25 days from 14 February 2019 to 11 March 2019. Of those invited, 16,423 (3.9%) women started the survey and 10,371 (2.4%) completed it in its entirety. Additional details of survey design and administration have been published previously.[13] Survey protocol was approved by the Ethics Committee of St. Mary's University (SMEC_2018-19_011), Twickenham, UK and informed consent was obtained prior to participants providing responses.

Participants were asked to retrospectively recall how many periods they had in the last year and were given options to select "0-3," "4-6," "7-10," "11-13," "14-16," "17-19," or "19+." AO was defined as reporting 0-10 periods, eumenorrhea as 11-16 periods, and polymenorrhea as ≥17 periods annually. Categories for menstrual cycle status were based on previously published characteristics of 612,613 women, in which 92% reported menstrual cycle intervals between 21 to 35 days.[14] A regular 21-35 day menstrual cycle results in approximately 11-17 periods per year.

Participants were also asked to select which exercise modalities they regularly participated in at least once per week (Table 1). Weekly exercise volume was quantified by asking participants to recall how much time they usually spent per week doing high intensity training (HIT; "hard and fast breathing, can't hold a conversation"), moderate intensity training (MIT; "hard breathing, can hold a conversation"), or low intensity training (LIT; "easy breathing") over the last month with the option to select "none," "0-30 minutes," "30 minutes-1 hour," "1-2 hours," "2-3 hours," "3-4 hours," "4-5 hours," "5-6 hours," "6-7 hours," "7-8 hours," "8-9 hours," "9-10 hours," or "10+ hours."

Only participants with complete survey responses were included in the present analyses (n = 10,371); from which 6,666 (64.3%) were excluded for the following reasons: reporting never having had a period (primary amenorrhea); currently pregnant / breastfeeding / started going through menopause / menopausal in the last year; diagnosed with polycystic ovary syndrome / endometriosis / premature ovarian failure / excess prolactin production / endometrial polyps or fibroids / adenomyosis / pelvic inflammatory disorder / cancers affecting the uterus or cervix; currently using hormonal contraceptives including implants / injections / hormonal intrauterine devices / vaginal rings / oral contraceptive pills / oestrogen patches / hormonal replacement therapies; or had a hysterectomy. Additionally, those identified as extreme outliers for body mass index (BMI) or age (3*interquartile range [IQR]) were removed along with those who reported having ≥17 menstrual cycles in the last year (polymenorrhea). A total of 3,705 (35.7%) women were included in final analyses.

Chi-square tests were used to evaluate associations between AO risk and categorical variables (country, sport). Group differences between AO vs. eumenorrheic participants for age and BMI were assessed using Mann Whitney U-tests as continuous variables were non-normally distributed. Logistic regressions assessed associations between LIT, MIT, and HIT volume categories and AO risk in univariate models, followed by models adjusted for age and BMI. Categories with the most frequent responses for LIT (2 to 3 h; 20.8% [772/ 3,705] of responses), MIT (2 to 3 h; 22.5% [835/ 3,705] of responses), and HIT (1 to 2 h; 22.9% [850/ 3,705] of responses) were selected as reference categories. Remaining categories were collapsed such that each category constituted >10% of responses. Statistical significance was set at $p < 0.05$. All statistical comparisons were made using SPSS (v.27.0) software.

Results

Demographic information for the included sample (n = 3,705) along with prevalence for AO (n = 576; 16%) or eumenorrhea (n = 3,129; 84%) based on age, BMI, country, and sport are provided in Table

1. AO women were younger and had a lower BMI compared to the eumenorrheic group. AO was not associated with country of origin or most exercise modes reported. However, women who participated in dance class/dance-based fitness classes were more likely to have AO than women who did not participate in dance despite having similar BMI (p = 0.16) and age (p = 0.21).

Table 2 displays unadjusted and adjusted odds ratios with 95% confidence intervals for AO risk based on weekly LIT, MIT, and HIT volume categories. Compared to 2 to 3 h/week of LIT, participating in ≥ 7 h/week of LIT was associated with increased AO risk while participating in ≤ 30 min/week of LIT was associated with decreased risk of AO. Similarly, participating in ≥ 6 h/week of MIT or ≥ 5 h/week of HIT was associated with increased risk of AO compared to 2 to 3 h/week of MIT and 1 to 2 h/week of HIT, respectively.

Discussion

In our analyses of 3,705 women representing multiple nationalities and sports, 16% (n = 574) reported AO, i.e., infrequent (≤ 10 menstrual cycles) or no menses in the last year. Weekly exercise volume above a certain threshold increased AO risk, regardless of the intensity it was performed. For example, women who reported LIT volumes ≥ 7 h/wk, MIT volumes ≥ 6 h/wk, or HIT volumes ≥ 5 h/wk compared to 2 to 3 h/wk for LIT and MIT and 1 to 2 h/wk for HIT had a ~40% greater risk of AO. Collectively, these associations suggest that excessive weekly exercise volume, of any intensity, may increase odds of developing AO among physically active women.

A comprehensive understanding of factors contributing to the greater prevalence of AO among exercising women remains elusive; however, intensified exercise training has been theorized to increase AO risk.[4, 15, 16] Initial work corresponding to the influx of women competing in endurance events such as the marathon during the 1980's attributed higher training volumes and/or intensity to the greater prevalence of AO observed among certain female athletes. For example, frequency of amenorrhea was shown to positively correlate with weekly mileage in runners, [11, 12] but possible differences in intensity of training between runners completing fewer vs. more miles per week was not considered. Russell et al. (1984) also observed (unspecified) reductions in training to result in resumption of normal menses among oligomenorrheic club-level swimmers practicing 25 hours/week.[17] Further accounts supported increases in the frequency of menstrual cycle dysfunction with initiation of controlled exercise training interventions, but were conducted in untrained women and as such involved increases in the volume and intensity of usual activity.[9, 10] While the conclusions of these earlier studies generally support periods of intensive physical training contribute to greater AO frequency in physically active women, they do little to clarify whether AO risk is modified by certain specific training characteristics, such as exercise volume or intensity.

One of our primary findings is the association between exercise volume and increased risk of AO, irrespective of exercise intensity. We found AO risk to be elevated to a similar extent for women reporting LIT, MIT, and HIT volumes comprising the top 10-16% of responses. The increase in AO risk among women who report relatively high weekly exercise volumes may plausibly be related to greater exercise energy expenditure and increased likelihood of low energy availability with longer duration training sessions. Additionally, greater exercise volume might also indicate a higher frequency of training sessions performed per week, which due to the anorexigenic effect of acute exercise that lasts for several hours, could result in an inadequate intake of calories to match energy expenditure between subsequent bouts [18]. Previous work has shown that the risk of low energy availability increases for every hour of exercise per week, but is not dependent on intensity of sport among recreational exercisers [19]. As such, increased risk of AO with greater exercise volume may be attributed to a higher likelihood of low energy availability with due to exercise energy expenditure uncompensated for by diet rather than the stress of exercise itself. Findings from Loucks et al. (1998) demonstrating no disruptive effects of 4 days of exercise energy expenditure equivalent to 30 Kcal/ kg lean body mass/ day when energy intake is matched provide support for this theory.[20] However, additional controlled interventions held over a longer duration are needed to determine whether habitually elevated exercise volume negatively influences AO risk independent of energy availability.

Interestingly, reporting LIT volumes ≤ 30 min/week was associated with reduced AO risk compared to 2 to 3 h/week while similar associations were not observed for MIT or HIT. Greater volumes of LIT may reflect exercise sessions that are non-specific to competitive training objectives, such as adding in "junk miles" or cross-training sessions for the purpose of increasing caloric expenditure rather than improving fitness or a specific sports skill. In support of this theory, Tomten et al. (1996) found long-distance runners with regular and irregular menstrual cycles to practice similar amounts of HIT (sessions >85% maximum heart rate), while women with irregular cycles engaged in more LIT (sessions <85% maximum heart rate).[21] Ravi et al. (2021) also observed higher daily step counts despite similar reported sport-specific volumes among AO versus eumenorrheic Finnish athletes, with a difference of ~5,000 steps per day between groups.[1] As such, the reduced AO risk we observed for women reporting the lowest amounts of LIT per week may be reflective of differences in exercise session intention and susceptibility to low energy availability.

Our finding that AO risk was not increased to a greater extent with HIT vs. LIT or MIT contradicts previous evidence suggesting higher training intensities have a suppressive effect on ovarian sex hormone production. The stimulatory effects of *acute* high-intensity exercise on β-endorphin[22] or glucocorticoid release[23] have been cited as reasons for AO in women undergoing intensive exercise training due to interaction with the hypothalamic-pituitary-adrenal axis and suppression of luteinizing hormone.[17] However, some evidence suggests *chronic* strenuous exercise training lowers basal plasma β-endorphin concentrations,[24] and blunts the rise in plasma β-endorphin and glucocorticoid release[25] experienced with acute high-intensity exercise. Such adaptions oppose the heightened endocrine response to exercise stress observed in women with AO.[26] As such, exercise intensity per se, may not increase AO risk.

Furthermore, previous evidence suggests that HIT, only when combined with low energy availability, may result in AO. For example, 4 days of performing high-intensity (70% maximal aerobic capacity) and high-volume (~3 hours/ day) exercise with low energy availability has been shown to disrupt luteinizing hormone pulsatility.[20] Whereas, the same exercise intervention did not have an effect on luteinizing hormone when energy expenditure was balanced with energy intake.[20] Performing more HIT has also been linked to improved BMI and fat free mass index in anorexia nervosa patients,[27] and it has been suggested that HIT may increase *ad libitum* caloric intake to a greater extent than LIT in the meal directly following exercise in recreationally active women.[28] These energy balancing effects might be attributed more to a psychological (i.e., self-granted "allowance" to eat more after a training session that is deemed as strenuous vs. non-strenuous) versus physiological response as there is inconsistency in the literature and a paucity of data collected in women to support the effects of exercise intensity on appetite.[27, 29] Accordingly, as our findings support, modifications in exercise volume rather than session intensity may have a greater influence on AO risk.

The relatively low prevalence of AO reported in our sample compared to other previous accounts could be attributed to the median age of participants (40 years [Quartile 1, Quartile 3: 30, 45]) as previous work has demonstrated greater resiliency against reductions in luteinizing hormone with low energy availability attained through diet and exercise intervention in women as gynecological age advances.[30] Alternatively, it could be attributed to the wide-range of competitive levels (i.e., recreational to professional athletes) and sport types of exercisers who use the STRAVA™ exercise application. The diversity of sport type and ability level along with the multinational representation of survey respondents is also a strength of our investigation. Our sample represents a group of physically active women who were users of the STRAVA™ exercise application, and therefore their exercise and diet habits likely differ from a more general population. Notably, the majority of our sample met minimum moderate to vigorous physical activity recommendations of ≥ 150-300 min/week of moderate or ≥ 75-150 min/week of vigorous aerobic activity or an equivalent combination of moderate and vigorous activity (n = 3168; 86%).

The self-report mode of assessment and necessity of survey participants to have access to technology are identifiable limitations of our analyses. While self-report surveys facilitate greater participation, recall bias is possible, and we cannot exclude the possibility of recall or social desirability biases. To minimize the latter, only participants with complete survey responses were included and those who were identified as extreme outliers for age and BMI were removed. Nevertheless, conclusions of this research should be confirmed by more controlled, objective measures (i.e., accelerometry, hormonal confirmation of AO). Further, as this survey was administered cross-sectionally, additional work is needed to establish how changes in exercise volume and intensity may longitudinally influence AO risk.

Conclusion

Our analyses of 3,705 women representing multiple nationalities and sports suggest AO risk is influenced by greater exercise training volume, irrespective of intensity. Women reporting LIT, MIT, or HIT volumes comprising the top 10-16% of responses had a ~40% increased risk of AO. Collectively, these findings indicate certain habitual exercise training characteristics, such as weekly volume, should be considered in the management of AO among physically active women.

Practical Implications

- Our primary findings suggest that women who participate in relatively high weekly volumes of exercise, regardless of the intensity at which exercise sessions are performed, are at an increased risk for irregular or missed periods.
- Participating in minimal amounts of low intensity training (≤ 30 min/week) may be a strategy to decrease the risk for irregular or missed periods.
- Practitioners should consider assessing exercise volume as a risk factor for irregular or missed periods among physically active women.

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Declarations of Interest

M.N.B., S.J.C., and J.M.B. have no competing interests to declare. G.B., C.R.P., and J.A.F., are employees or consultants for Orreco and creators of the FitrWoman application.

Data Availability

Data underpinning these analyses are available from the authors upon request.

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Table 1. Descriptive information for the sample meeting inclusion criteria (n = 3,705) and for women classified as AO vs. eumenorrheic

	Total Sample n = 3,705	**AO** n = 576 (16%)	**Eumenorrheic** n = 3,129 (84%)	**p-value**
Age (years), median (Q1 - Q3)	40 (30 - 45)	35 (25 - 35)	40 (30 - 45)	<0.01*
BMI (kg/m^2), median (Q1 - Q3)	22.1 (20.5 – 24.2)	21.4 (20.0 – 23.5)	22.2 (20.6 – 24.4)	<0.01*
Country n (%)				0.70
Brazil	384 (10)	50 (13)	334 (87)	
France	652 (18)	97 (15)	555 (85)	
Germany	489 (13)	79 (16)	410 (84)	
Spain	540 (15)	91 (17)	449 (83)	
UK	761 (21)	119 (16)	642 (84)	
USA	879 (24)	140 (16)	739 (84)	
Sport n (%)				
Running	2860 (77)	447 (16)	2413 (84)	0.80
Cycling	1571 (42)	244 (16)	1327 (84)	0.98
Weight Training	1265 (34)	213 (17)	1052 (83)	0.12
Gym Based Classes	1009 (27)	159 (16)	850 (84)	0.83
Other Prolonged Exercise	684 (19)	110 (16)	574 (84)	0.67
Swimming	638 (17)	113 (18)	525 (82)	0.10
Cross Trainer	424 (11)	79 (18)	345 (81)	0.06
Dance Class	206 (6)	45 (22)	161 (78)	0.01*

Team Sports	156 (4)	29 (19)	127 (81)	0.28
Racquet Sports	96 (3)	13 (14)	83 (86)	0.58
Martial Arts	52 (1)	6 (12)	46 (88)	0.42

AO = amenorrhoeic / oligomenorrheic. BMI = body mass index. UK = United Kingdom / Ireland. USA = United States of America. Q1= quartile 1. Q3= quartile 3. *p < 0.05 between AO and eumenorrheic groups.

Table 2. OR with 95% CI for AO dependent on self-reported volume of exercise training intensity

	n (%)	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
LIT					
≤ 30 min	416 (11)	0.64 (0.44 - 0.92)	0.02*	0.65 (0.44 – 0.94)	0.02*
30 min to 1 h	410 (11)	1.12 (0.81 - 1.56)	0.48	1.14 (0.82 – 1.58)	0.45
1 to 2 h	672 (18)	1.06 (0.80 – 1.41)	0.69	1.05 (0.79 – 1.41)	0.72
2 to 3 h	772 (21)	Ref.		Ref.	
3 to 4 h	450 (12)	1.20 (0.88 - 1.65)	0.25	1.20 (0.87 – 1.64)	0.27
4 to 7 h	605 (16)	0.92 (0.68 – 1.25)	0.61	0.91 (0.67 – 1.24)	0.55
≥ 7 h	380 (10)	1.51 (1.10 – 2.07)	0.01*	1.43 (1.04 – 1.96)	0.03*
MIT					
≤ 1 h	431 (12)	1.09 (0.79 – 1.51)	0.61	1.13 (0.81 – 1.58)	0.47
1 to 2 h	630 (17)	0.87 (0.64 – 1.18)	0.36	0.85 (0.63 – 1.16)	0.32
2 to 3 h	835 (23)	Ref.		Ref.	
3 to 4 h	613 (17)	1.23 (0.92 – 1.64)	0.17	1.20 (0.90 – 1.61)	0.21
4 to 6 h	615 (17)	1.24 (0.93 – 1.65)	0.15	1.17 (0.88 – 1.57)	0.28
≥ 6 h	581 (16)	1.45 (1.09 – 1.93)	0.01*	1.46 (1.10 – 1.95)	0.01*
HIT					
≤ 30 min	405 (11)	1.16 (0.84 – 1.61)	0.37	1.26 (0.91 – 1.78)	0.17
30 min to 1 h	706 (19)	0.82 (0.61 – 1.10)	0.18	0.84 (0.62 – 1.13)	0.24
1 to 2 h	850 (23)	Ref.		Ref.	
2 to 3 h	707 (19)	1.11 (0.84 – 1.47)	0.46	1.08 (0.81 – 1.43)	0.59
3 to 5 h	609 (16)	1.30 (0.98 – 1.73)	0.07	1.28 (0.96 – 1.70)	0.10
≥ 5 h	428 (12)	1.44 (1.06 – 1.95)	0.02*	1.41 (1.03 – 1.92)	0.03*

OR = odds ratio unadjusted and adjusted for age and BMI. Ref. = reference category. LIT = low intensity training. MIT = moderate intensity training. HIT = high intensity training. *$p < 0.05$ between AO and eumenorrheic groups.