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Prospective study of food intake changes in adolescent elite athletes

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ABSTRACT

Background Inadequate energy intake among athletes can lead to low energy availability (LEA) which in turn can result in negative effects on athletic performance and physical and psychological health. This syndrome is known as relative energy deficiency in sports (REDs).

Objective To map perceived changes in overall food intake among adolescent athletes during the previous year, as well as weekly changes during a 3-month period and to examine how these changes are associated with mental health, physical load and sex.

Methods A total of 168 high school athletes from eight different sports participated. A baseline questionnaire examined changes in training habits and food intake in the past year, mental health (short version of the Warwick-Edinburgh Mental Well-being Scale (SWEMWBS)), injury history and previous periods of poor psychological health. Weekly digital questionnaires for 3 months tracked weekly physical and mental load and changes in food intake. Comparative and correlation analyses were performed with p<0.05 considered significant.

Results A decreased food intake during the previous year was reported more often among athletes experiencing periods of poor mental health than those without such periods (10% vs 2%; p=0.034). Athletes who decreased their food intake reported lower mental well-being than athletes who increased their food intake (mean difference in SWEMWBS=4.69±1.57; p=0.021). Over a 3-month period, most athletes did not change their food intake, yet fluctuations in physical load were reported.

Conclusion This study showed that athletes experiencing lower mental health or period(s) of poor mental health reported decreased food intake more often than those with better mental health or those without period(s) of poor mental health. In addition, the mismatch found between perceived weekly changes in overall food intake and changes in physical load during the same time period could potentially result in an increased risk for LEA.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Relative energy deficiency in sports (REDs) is a potentially life-threatening syndrome with high prevalence, and it is necessary to identify athletes at risk and to insert preventive measures.

WHAT THIS STUDY ADDS

⇒ Adolescent athletes with poor mental health might be at risk for the development of REDs. In addition, adolescent athletes might fail to match energy expenditure with energy intake, which potentially increases the risk of REDs.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Mental health status should be incorporated while screening for REDs. Nutritional education is necessary to prevent energy imbalance among young athletes.

INTRODUCTION

Optimising nutritional strategies is a well-known way of achieving peak athletic performance. Good nutritional habits can boost athletic success, speed up recovery time, enhance training response and reducethe risk of illness and injuries.[1] An inadequate nutrition regime has been shown to have opposite effects.[2]

Relative energy deficiency in sports (REDs) is a syndrome used to describe physiological and psychological consequences following low energy availability (LEA) among athletes.[2] These consequences include, yet are not limited to, negative effects on endocrine function, immune system, muscle protein synthesis, injury risk, reproductive, psychiatric, cardiovascular and bone health. The aetiology behind LEA is multifactorial and might be explained by, for example, eating disorders (ED), disordered eating (DE) and limited nutritional knowledge.[3]

Most sports nutrition guidelines are primarily designed for the adult elite athlete, although adolescent athletes have a higher risk of developing LEA as well as ED and DE.[4 5] Adequate energy intake during puberty is challenged by the rising energy demands due to rapid body growth and increased training volume and intensity.[1] Additionally, stressors such as pressure to perform, demanding educational programmes, new social interactions, hormonal fluctuations and transition from youth to senior sport may also affect energy intake in adolescent athletes, as well as body image issues that are common among adolescents.[6] LEA can reduce or disturb the levels of oestrogen, progesterone and testosterone and potentially lead to

Table 1 Demographics of the study participants

Total	168 (100%)
Sex	
Male	104 (62%)
Female	64 (38%)
Sport	
Ice Hockey	51 (30%)
Soccer	44 (26%)
Track and Field	34 (20%)
Bandy*	17 (10%)
Floorball†	9 (6%)
Gymnastics	7 (4%)
Fencing	5 (3%)
Tennis	1 (1%)
High school year‡	
1	57 (37%)
2	61 (39%)
3	37 (24%)
Moved from home	
No	148 (88%)
Yes	20 (12%)

Values in numbers (%).
*Bandy is a team sport played on ice with six players and one goalkeeper. Each player uses a curved stick to control and pass the ball on a rectangular rink 30–45 m×60–90 m.
†Floorball is an indoor team sport with five field players and a goalkeeper. Each player uses a lightweight stick to control a plastic ball with holes on a rectangular court with a 50 cm high board.
‡Missing values: 13.

delayed puberty, irregular or absent menstruation and affect reproductive function.[4 5] Energy deficiency further weakens the immune system, making athletes more prone to injuries and illnesses,[7] and psychological disorders can both be a potential cause and a consequence of REDs.[2] Furthermore, LEA has negative impacts on bone formation and structure, increasing the risk of (stress) fractures and long-term osteoporosis.[8] Since adolescence is crucial for developing strong and healthy bones, preventing LEA among young athletes is essential.[2]

The prevalence of LEA and REDs among athletes is worrisome, and there is limited research about potential risk factors for the development of the syndrome.[2] The International Olympic Committee (IOC) encourages more studies to identify athletes at risk of developing LEA and highlights the importance of raising awareness of REDs in the sporting community.[2]

Hence, in order to identify risk factors for LEA and REDs, more knowledge needs to be attained regarding food intake behaviour among adolescent athletes over time. This study aims to map perceived changes in overall food intake among adolescent athletes during the previous year, as well as weekly changes during a 3-month period, and to examine how these changes are associated with mental health, physical load and sex.

METHODS

This is a prospective cohort study. The study is part of the Healthy Injury-Free Adolescent Athletes Project (HIFAA).[9] The HIFAA project, including this study, has ethical approval from the Swedish Ethics Committee with the diary number 2021-05496-01.

Study population

The inclusion criteria for participating in this study were (1) being a current registered student at a Swedish high school and (2) training and competing in a sport with the subjective ambition to reach the highest national or international level. Athletes training at a recreational level were excluded from the study.

Invited high schools were identified through local sports clubs, national federations, webpages and personal contacts. Identified schools were distributed across the nation in both urban and suburban environments. All athletes received oral and written information about the project and gave written informed consent before inclusion. The individual answers and results were strictly confidential, stored in password-protected files and handled only by researchers involved in the project; hence, data were not shared with, for example, coaches, teachers or parents. Inclusion was voluntary, and athletes were able to cancel their participation at any moment.

Data collection

Included athletes submitted a baseline questionnaire at the beginning of the study. Once a week they received an automatic text message with a personal link to the weekly questionnaire (online supplemental material S1). If a student did not answer, a reminder text message was automatically sent the following day. Both questionnaires were digital and connected to a web application, which was developed for the HIFAA project. Athletes were enrolled between December 2022 and February 2023, with data for the 3-month study period of weekly questionnaires collected from March to June 2023.

Baseline questionnaire

The baseline questionnaire consisted of questions regarding demographics, habitual weekly training and competing frequency and a history of serious injury in the past year (online supplemental material S2). A serious injury was defined as being away from regular training and/or competition for 1 month or more.

Changes in food intake and changes in exercise habits during the previous year were examined using a five-level ranking scale (decreased a lot, decreased, no change, increased and increased a lot).

Mental health was measured using two different methods: (1) the short version of the Warwick-Edinburgh Mental Well-being Scale (SWEMWBS)[10 11] and (2) the

Table 2 Changes in food intake during the previous year compared between age, sex, moved from home, serious injury, year in high school, SWEMWBS score and poor mental health

	Decreased (n=6)	No change (n=68)	Increased (n=76)	Increased a lot (n=15)	Total (n=165)*	P value†
Age, mean (SD)	17.5 (0.55)	17.2 (0.82)	16.7 (0.70)	16.5 (0.74)	16.9 (0.79)	**<0.001**
Sex						
Female	3 (4.8)	31 (50.0)	23 (37.1)	5 (8.1)	62 (100)	0.253
Male	3 (2.9)	37 (35.9)	53 (51.5)	10 (9.7)	103 (100)	
Moved from home						
No	6 (4.1)	62 (42.2)	69 (46.9)	10 (6.8)	147 (100)	0.053
Yes	0 (0)	7 (35.0)	8 (40.0)	5 (25.0)	20 (100)	
Serious injury						
No	1 (1.0)	40 (41.7)	45 (46.9)	10 (10.4)	96 (100)	0.202
Yes	5 (7.0)	29 (40.8)	32 (45.1)	5 (7.0)	71 (100)	
High school year						
1	1 (1.8)	15 (26.3)	33 (57.9)	8 (14.0)	57 (100)	**0.004**
2	3 (5.0)	27 (45.0)	27 (44.0)	3 (5.0)	60 (100)	
3	2 (5.4)	22 (59.5)	11 (29.7)	2 (5.4)	37 (100)	
SWEMWBS, mean (SD)	20.98 (5.06)	24.14 (3.78)	25.57 (3.54)	23.95 (3.69)	24.68 (3.8)	‡
Poor mental health						
No	2 (1.6)	48 (38.4)	63 (50.4)	12 (9.6)	125 (100)	**0.034**
Yes	4 (9.5)	21 (50.0)	14 (33.3)	3 (7.1)	42 (100)	

Values in number of athletes (%) unless specified. No participant answered ‘decreased a lot’.
Bold number indicates a statistical significance (p<0.05).
*Missing values: 3.
†Kruskal-Wallis test.
‡One-way analysis of variance test with Tukey’s post hoc test revealed a significant difference between increased and decreased, p=0.021.
SWEMWBS, short version of the Warwick-Edinburgh Mental Well-being Scale.

question ‘Have you ever experienced poor mental health for a period (daily for at least 2 weeks) so that you experienced obvious difficulties in functioning in everyday life and sports?’ (yes or no). The SWEMWBS has been translated and validated into Swedish and has commonly been applied in national surveys for the adolescent population.[10 11] It has shown good reliability and internal consistency (Cronbach’s alpha 0.86–0.88), as well as good face-related and criterion-related validity.[10] It consists of seven statements about the athlete’s well-being during the previous 2 weeks and is answered on a five-level ranking scale (never, seldom, sometimes, often and always). Answers from the seven statements of the SWEMWBS were converted to numbers (1–5, 1: never and 5: always). The sum of all seven statements was converted to a metric scale (7–35, 7: worst possible and 35: best possible), according to a table published by the Public Health Agency of Sweden (‘Folkhälsomyndigheten’).[12] This sum was the SWEMWBS score. The second question (yes/no) has previously been used in a survey that retrospectively evaluated Swedish national team athletes.[13]

Weekly questionnaire

The product of self-reported previous week’s hours of training/competing and average weekly rating of perceived exertion (RPE), estimated on the Borg Scale (1 (very easy) to 10 (very hard)), was used to monitor weekly physical load as the session RPE (sRPE) (training/competing hours×RPE).[14] Weekly mental load was monitored with four statements (fatigue, sleep, stress and mental recovery) and was answered with a five-level ranking scale (very poor, poor, average, well and very well). Answers from the four statements were converted to numbers (1–5, 1: very poor and 5: very well). The sum of the four statements (4–20, 4: worst possible and 20: best possible) was the total weekly wellness score. Self-reported wellness scores, to monitor training response/load, have commonly been used in research, clinic and national systems, and these scores have been reported to be valid to track changes in fitness and fatigue[15 16] (online supplemental material S3). Changes in food intake during the previous week were examined by the question, ‘Based on your regular food intake, how have you changed your food intake in the past 7 days?’ and were answered on a five-level ranking scale (decreased a lot, decreased, no change, increased and increased a lot).

Statistical analysis

The statistical analysis was carried out in IBM SPSS Analytics V.29. Descriptive data are described with

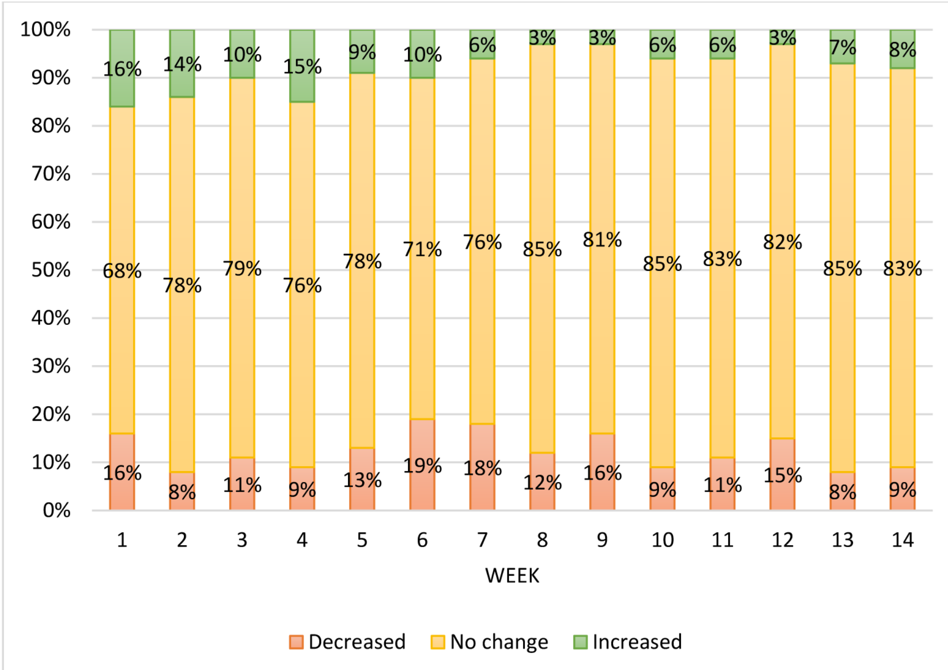

Figure 1 The distribution of reported changes in food intake per week among 126 athletes. The y-axis represents the percentage of each reported change in food intake, and the x-axis represents each week. No participants answered 'decreased a lot' or 'increased a lot'. The weekly response rate varied between 37% and 79%, with a mean weekly response rate of 56%.

mean±SD for continuous variables and numbers (%) for categorical variables unless specified. Normal distribution was tested with the Kolmogorov-Smirnov normality test. The Kruskal-Wallis test, Mann-Whitney U test and one-way analysis of variance with Tukey's post hoc test were used for comparison between groups. The χ^2 test was used for categorical analyses. Correlation analyses were performed between changes in food intake and changes in training habits in the past year and between weekly changes in food intake and sRPE and wellness score, using Spearman's rank-order correlation test (rs). Values (rs) between 0.9 and 1.0 indicated very high correlation, 0.7–0.9 high correlation, 0.5–0.7 moderate correlation, 0.3–0.5 weak correlation and <0.3 neglectable correlation.[17] All tests were two-sided with a level of p<0.05 considered significant.

RESULTS

Demographics of the study population

All invited athletes agreed to participate and answered the baseline questionnaire (n=168; females n=64; males n=104). The mean age was 16.9±0.79 years old without an age difference between the sexes. The demographic data are shown in table 1. Missing values are due to absent answers.

Baseline questionnaire

Athletes who had experienced one or more periods of poor mental health reported decreased food intake more often than those without such periods (table 2). Experiencing poor mental health was more common among females than males (34% vs 19%; p=0.034).

The mean SWEMWBS score for all athletes was 24.68±3.8 (table 2). Females reported lower mental health than males (23.12±3.5 vs 25.6±3.7, p<0.001). Athletes who decreased their food intake reported lower mental health than athletes who increased their food intake (mean difference=4.69±1.57; p=0.021). There was a statistically significant correlation between changes in exercise habits over the past year and changes in food intake during the same period (rs=0.176; p=0.023).

Weekly questionnaires

14 weekly questionnaires were sent out, and 126 of the athletes responded to at least one of them. The remaining 42 athletes did not respond to any weekly questionnaire and are considered 'non-responders'. Non-responders were more common among males (n=32, 30%) than females (n=10, 16%; p=0.028) and more common among athletes without a serious injury in the past year (n=31, 32%) than athletes with one or more (n=11, 16%; p=0.015). There were no differences between responders and non-responders regarding sport, moving, weekly training load, change in food intake, mental health, age, SWEMWBS score or year in high school.

The distribution of reported changes in food intake per week is shown in figure 1, and changes in food intake between sex and different sports are shown in table 3. A decreased food intake was reported more often among females than males, and an increased food intake was reported more often among males than females (table 3).

The median value each week for sRPE, wellness score and changes in food intake are shown in figure 2. There was a weak correlation between the change in food intake

Table 3 Weekly changes in food intake over 3 months (14 weeks) compared between sex and sports

	Decreased	No change	Increased	Total	P value*
Sex†					
Female (n=54)	51 (11.1)	366 (79.6)	43 (9.3)	460 (100)	0.003
Male (n=72)	38 (7.0)	422 (77.7)	83 (15.3)	543 (100)	
Sport‡					
Ice hockey	33 (10.9)	227 (75.2)	42 (13.9)	302 (100)	0.733
Bandy	6 (5.3)	90 (79.6)	17 (15.0)	113 (100)	
Floorball	1 (1.5)	61 (89.7)	6 (8.8)	68 (100)	
Gymnastics	12 (16.4)	56 (76.7)	5 (6.8)	73 (100)	
Track and field	18 (9.0)	155 (77.5)	27 (13.5)	200 (100)	
Soccer	14 (6.8)	168 (81.2)	25 (12.1)	207 (100)	
Fencing	3 (10.3)	23 (79.3)	3 (10.3)	29 (100)	
Tennis	2 (18.2)	8 (72.7)	1 (9.1)	11 (100)	

Values in number of reported answers (%). No participant answered ‘decreased a lot’ or ‘increased a lot’.
*Kruskal-Wallis test.
†Total number: 126 (females 54 and males 72).
‡Total number: 126 (ice hockey 32, bandy 14, floorball 7, gymnastics 7, track and field 31, soccer 30, fencing 4 and tennis 1).

and wellness score in week 3 (rs=0.319, p=0.007) and week 14 (rs=0.365, p=0.012) and between the change in food intake and sRPE in week 2 (rs=0.339, p=0.003), week 4 (rs=0.313, p=0.002) and week 5 (rs=0.340, p<0.001). Other correlations between either change in food intake and wellness score or between change in food intake and sRPE were neglectable (rs<0.3) or not significant (p>0.05).

When stratifying athletes into low (under the 25th percentile), medium (between the 25th and 75th percentile) and high (over the 75th percentile) SWEMWBS scores, athletes with lower SWEMWBS scores at baseline reported decreased food intake more often than athletes with higher SWEMWBS scores at baseline (14% vs 7% p=0.026) (figure 3).

DISCUSSION

The most important finding of this study was that a statistically significant association between change in food intake and mental health was shown in adolescent athletes. Athletes who had experienced one or more periods of poor mental health reported decreased food intake during the previous year more often than those

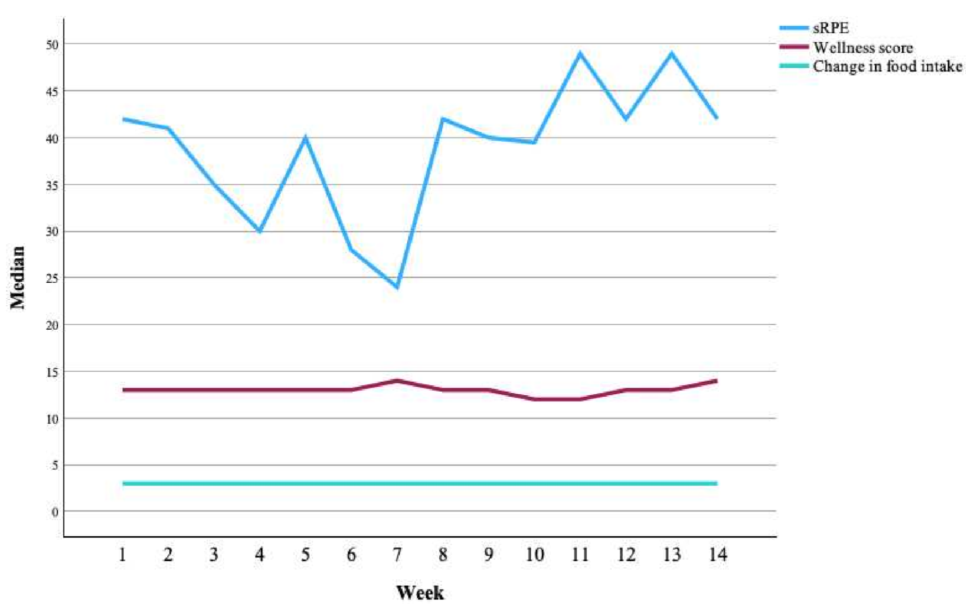

Figure 2 Median value each week for sRPE (training/competing hours×RPE; 1–10; 1: lowest and 10: highest), wellness score (4–20; 4: worst possible and 20: best possible) and change in food intake (1–5; 1: decreased a lot and 5: increased a lot). RPE,rating of perceived exertion; sRPE, session RPE.

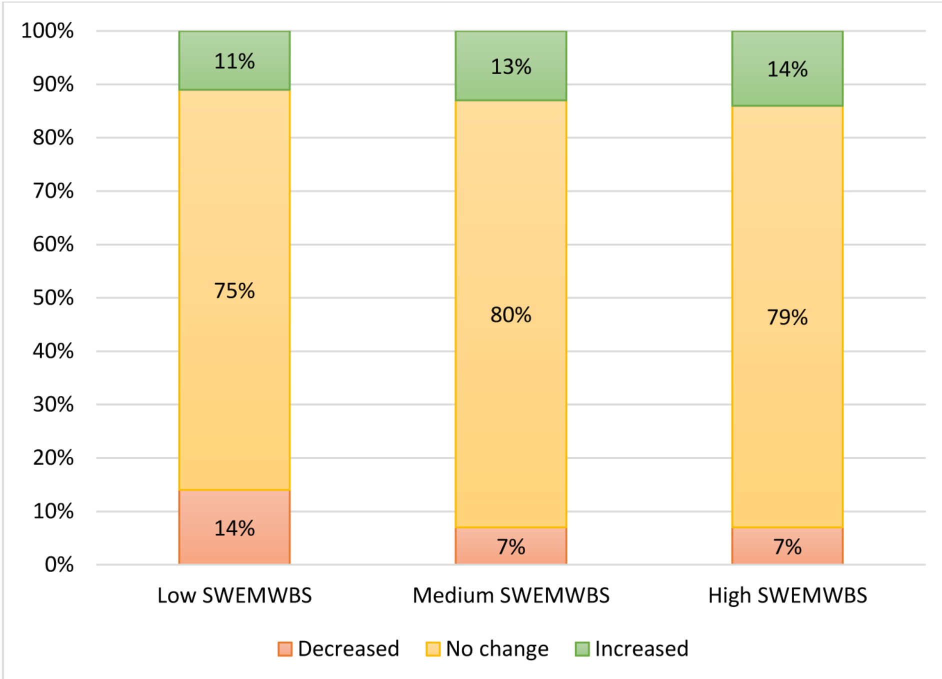

Figure 3 Distribution of reported changes in food intake for 3 months among 126 athletes divided into three levels of SWEMWBS scores. Low=scores in the lowest 25th percentile (256 reported changes), medium=scores between the 25th and 75th percentile (583 reported changes) and high=scores in the highest 75th percentile (164 reported changes). SWEMWBS, short version of the Warwick-Edinburgh Mental Well-being Scale.

without such periods. In addition, athletes who decreased their food intake during the previous year reported lower SWEMWBS scores than athletes who increased their food intake. Moreover, athletes with reduced mental health at baseline were more likely to decrease their food intake during the study period of 3 months compared with those with higher SWEMWBS scores (better mental health).

The results of this study indicate that the level of mental health among athletes who decreased their food intake during the previous year is lower than that of the general Swedish adolescent population (mean 24.6±5.05).[18] In contrast, athletes who remained or increased their food intake had scores similar to the general population.[18] To the best knowledge of the authors, no other studies have examined the association between food intake changes and mental health; however, other studies have found that negative energy balance among athletes might be associated with poor mental health.[19–21]

The association between mental health and food intake in this study may have been influenced by confounding factors, such as athletic injury or moving out of family housing, as these factors can affect food intake, yet no association was found between these factors and changes in food intake. However, few of the athletes decreased their food intake, and few moved out of family housing, which increases the risk of type-2 errors. Another possible confounding factor is 'psychiatric conditions', such as ED and DE, which affect both mental health and food intake.[22] These conditions are common among the athletic population, yet the prevalence is uncertain.[23] Furthermore, experiments have shown that negative energy balance can lead to mental illness, suggesting that factors reducing food intake, such as dieting to enhance performance, might also increase the risk of reduced mental health.[24] Additionally, combining high-level sport and education might be a stressful time for young athletes, which could interfere with both food intake opportunities and mental health.

Athletes with lower SWEMWBS scores at baseline were more likely to decrease their food intake over the 3-month period compared with those with higher SWEMWBS scores. This indicates that athletes with impaired mental health are at risk of reducing their food intake, which in turn increases their risk of LEA if energy output remains constant. Mental illness, such as depression, can cause reduced appetite, and a greater increase in appetite loss has been associated with greater severity of mental illness.[25] However, it is difficult to determine if impaired mental health is causing decreased energy intake or vice versa. Each factor may also worsen the other, which can cause a negative spiral in the long term for young athletes.

This study reported that a decreased food intake was more common among females than males. These findings are supported by other studies that have shown a higher prevalence of LEA, as well as ED and DE, among female athletes compared with male.[23 26] Furthermore, in this study, experiencing poor mental health and lower SWEMWBS score were more common among females than males, which may be influenced by several factors. Hormonal fluctuations, societal pressures and the greater prevalence of LEA among female athletes could all contribute to this disparity. These complex physiological and psychological interactions underscore the need for a more holistic approach to understanding the mental health challenges faced by female athletes.[27]

There were significant positive correlations between food intake and wellness score and sRPE, respectively. There was also a significant positive correlation between changes in exercise habits over the past year and changes in food intake during the same period. However, these correlations are considered weak (r=0.3–0.5) or negligible (r<0.3) based on the r-coefficient, which raises questions about their clinical significance.[17] Based on these findings, it is possible that energy intake among athletes might be insufficient to meet energy requirements due to fluctuating physical load while food intake remains unchanged.

The weekly screening of food intake and mental well-being is a strength of this study, capturing short-term fluctuations. However, the influence of training phases on these variables is important to consider. While this study did not focus on body mass reduction for competition, it is known that in aesthetic sports and some track and field events, athletes may reduce body mass during the competition phase, which could affect food intake and mental health.[28 29] However, in this study, no differences were found regarding sports. Evidence suggests that training phases, such as precompetition or competition, can impact both energy intake and mental health being.[30 31] During the competition phase, athletes may experience heightened psychological pressure, leading to stress-related changes in eating behaviours or intentional energy restriction, particularly in sports where body composition is emphasised. This may increase the risk of LEA and its negative effects on mental health.

The absence of correlation could be explained by 'anorexia of exercise' as studies have shown that both endurance and resistance training can decrease levels of the hunger hormone 'ghrelin', potentially disrupting energy intake.[32–34] However, appetite regulation is multifactorial, and it is important to consider other biomarkers involved in this complex process. For instance, leptin plays a significant role in energy homeostasis and appetite control by signalling energy sufficiency to the brain. In states of LEA, leptin levels tend to decrease, which can further impair appetite regulation and energy intake.[35] The interplay between ghrelin, leptin and other appetite-regulating hormones likely contributes to the challenge of maintaining energy balance during periods of high physical exertion.[35] If appetite is suppressed by a high physical load, it is important that athletes are well educated in sports nutrition to accomplish energy balance. Unfortunately, poor nutritional knowledge is common among athletes, thus making it a potential risk factor for LEA.[3 29 36 37] It is also possible that changes in food intake could occur in the week following an increase in training load, while this study only examined correlations within the same week.

There are several strengths to this study. This is, to the best knowledge of the authors, the first study to examine changes in food intake over time among adolescent athletes. Commonly used methods to measure food intake, such as 24-hour recalls and food records, are often found to be time-consuming, expensive and inappropriate to suite large-scale studies. The web application used in this study enabled a large cohort followed over a longer period, and the studied population represented a variety of adolescent athletes regarding sex, sport and age.

Limitations in this study are the non-participation of 42 athletes (25%) in the weekly questionnaires and the variation in weekly response rates. However, no statistical differences were shown between responders and non-responders when controlling for various factors. Furthermore, the distribution of reported food changes remained stable, suggesting that the impact of the response rate on study results might be of less importance. However, this study did not include a power analysis due to the aim of including a great number of athletes over a longer period. As the response rate varied, the power was reduced; hence, the risk of type-2 error was increased.

To evaluate mental health, the SWEMWBS and one question on perceived poor mental health were used.[10 11 13] However, interstudy comparisons may be challenging due to various methods examining different aspects of mental health. To enhance validity and generalisability, future studies might benefit from using the Sport Mental Health Recognition Tool 1 and the Sport Mental Health Assessment Tool 1 recently developed by the IOC.[38] Furthermore, food intake was assessed using a single-question, five-level scale. While this provided useful insights, it may limit the precision of the data. Although this study used a single-question approach to assess changes in food intake, we acknowledge the importance of validated tools such as the LEAF-Q as suggested by Melin *et al*,[5] which has been shown to effectively identify female athletes at risk of LEA and its associated health consequences. The method in the current study provides a broad, simplified means of tracking perceived changes in food intake, which could complement detailed screening tools like the LEAF-Q, particularly in large-scale, longitudinal studies where more frequent or complex data collection may be burdensome.

This study only provides a broad overview of perceived changes in food intake over time among adolescent athletes and cannot conclude absolute energy intake, LEA prevalence or food intake quality. Nevertheless, the aim of this study was to map perceived changes in overall food intake among adolescent athletes. By doing so, valuable and improved knowledge of food behaviour was attained, and identification of potential REDs risk groups was possible.

CONCLUSIONS

This study showed that changes in food intake were associated with mental health. Athletes experiencing lower mental health or having had a period(s) of poor mental health reported decreased food intake more often than those with higher mental health or those without such period(s) of poor mental health. These athletes could possibly be at risk of developing LEA. In addition, the mismatch found between perceived weekly changes in overall food intake and changes in physical load during the same time period could potentially result in an increased risk for LEA. Primary preventive strategies, such as nutritional education and screening, are suggested to prevent REDs.

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Contributors JA and IL initiated the HIFAA-study. JA, IL and ML was responsible for the conception of the study and the collection of data. JA and ML was responsible for the data analysis with consultation from Christer Johanson, who is acknowledged. ML wrote the first draft of the paper, which was critically revised by all authors (ML, IL, AH and JA). The final manuscript has been approved by all authors. JA acted as the guarantor of the study.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the Swedish Ethics Committee with the diary number: 2021-05496-01. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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REFERENCES

1 Burke L, Deakin V. Clinical Sports Nutrition. New York: McGraw-Hill, 2015.
2 Mountjoy M, Ackerman KE, Bailey DM, *et al*. 2023 International Olympic Committee's (IOC) consensus statement on Relative Energy Deficiency in Sport (REDs). *Br J Sports Med* 2023;57:1073–97.
3 Logue DM, Madigan SM, Melin A, *et al*. Low Energy Availability in Athletes 2020: An Updated Narrative Review of Prevalence, Risk, Within-Day Energy Balance, Knowledge, and Impact on Sports Performance. *Nutrients* 2020;12:835.
4 Gordon CM, Ackerman KE, Berga SL, *et al*. Functional Hypothalamic Amenorrhea: An Endocrine Society Clinical Practice Guideline. *J Clin Endocrinol Metab* 2017;102:1413–39.
5 Melin A, Tornberg AB, Skouby S, *et al*. The LEAF questionnaire: a screening tool for the identification of female athletes at risk for the female athlete triad. *Br J Sports Med* 2014;48:540–5.
6 Tatangelo G, McCabe M, Mellor D, *et al*. A systematic review of body dissatisfaction and sociocultural messages related to the body among preschool children. *Body Image* 2016;18:86–95.
7 Gleeson M. Immune function in sport and exercise. *J Appl Physiol* 2007;103:693–9.
8 Papageorgiou M, Dolan E, Elliott-Sale KJ, *et al*. Reduced energy availability: implications for bone health in physically active populations. *Eur J Nutr* 2018;57:847–59.
9 Lindman I, Ryman Augustsson S, Baranto A, *et al*. Prospective cohort study identifying risk factors for sports injuries in adolescent athletes: the Healthy Injury-Free Adolescent Athletes (HIFAA) study. *BMJ Open Sport Exerc Med* 2024;10:e002253.
10 Haver A, Akerjordet K, Caputi P, *et al*. Measuring mental well-being: A validation of the Short Warwick-Edinburgh Mental Well-Being Scale in Norwegian and Swedish. *Scand J Public Health* 2015;43:721–7.
11 Ringdal R, Bradley Eilertsen M-E, Bjørnsen HN, *et al*. Validation of two versions of the Warwick-Edinburgh Mental Well-Being Scale among Norwegian adolescents. *Scand J Public Health* 2018;46:718–25.
12 Folkhälsomyndigheten. Syfte och bakgrund till frågorna i nationella folkhälsoenkäten - Hälsa på lika villkor 2018. 2018.
13 Fahlström PG, Gerrevall P, Glemne M, *et al*. Vägarna till Landslaget. Stockholm: Sveriges Riksidrottsförbund, 2015.
14 Soligard T, Schwellnus M, Alonso J-M, *et al*. How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *Br J Sports Med* 2016;50:1030–41.
15 Jeffries AC, Wallace L, Coutts AJ, *et al*. Athlete-Reported Outcome Measures for Monitoring Training Responses: A Systematic Review of Risk of Bias and Measurement Property Quality According to the COSMIN Guidelines. *Int J Sports Physiol Perform* 2020;15:1203–15.
16 Crowcroft S, McCleave E, Slattery K, *et al*. Assessing the Measurement Sensitivity and Diagnostic Characteristics of Athlete-Monitoring Tools in National Swimmers. *Int J Sports Physiol Perform* 2017;12:S2–95.
17 Mukaka MM. Statistics corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Med J J Med Assoc Malawi* 2012;24:69–71.
18 Låftman SB, Modin B, Granvik Saminathen M, *et al*. Psychosocial School Conditions and Mental Wellbeing Among Mid-adolescents: Findings From the 2017/18 Swedish HBSC Study. *Int J Public Health* 2022;67:1605167.
19 Bomba M, Corbetta F, Bonini L, *et al*. Psychopathological traits of adolescents with functional hypothalamic amenorrhea: a comparison with anorexia nervosa. *Eat Weight Disord* 2014;19:41–8.
20 Giles DE, Berga SL. Cognitive and psychiatric correlates of functional hypothalamic amenorrhea: a controlled comparison. *Fertil Steril* 1993;60:486–92.
21 Marcus MD, Loucks TL, Berga SL. Psychological correlates of functional hypothalamic amenorrhea. *Fertil Steril* 2001;76:310–6.
22 Tan EJ, Raut T, Le LK-D, *et al*. The association between eating disorders and mental health: an umbrella review. *J Eat Disord* 2023;11:51.
23 Martinsen M, Sundgot-Borgen J. Higher prevalence of eating disorders among adolescent elite athletes than controls. *Med Sci Sports Exerc* 2013;45:1188–97.
24 Firth J, Gangwisch JE, Borisini A, *et al*. Food and mood: how do diet and nutrition affect mental wellbeing? *BMJ* 2020;369:m2382.
25 Paykel ES. Depression and appetite. *J Psychosom Res* 1977;21:401–7.
26 Matt SA, Barrack MT, Gray VB, *et al*. Adolescent Endurance Runners Exhibit Suboptimal Energy Availability and Intakes of Key Nutrients. *J Am Nutr Assoc* 2022;41:551–8.
27 Bulut S, Rostami M, Hajji J, *et al*. Psychological and Social Factors Influencing Eating Behaviors in College Athletes. *Health Nexus* 2024;2:99–105.
28 Wasserfurth P, Palmowski J, Hahn A, *et al*. Reasons for and Consequences of Low Energy Availability in Female and Male Athletes: Social Environment, Adaptations, and Prevention. *Sports Med Open* 2020;6:44.
29 Janiczak A, Devlin BL, Forsyth A, *et al*. A systematic review update of athletes' nutrition knowledge and association with dietary intake. *Br J Nutr* 2022;128:1156–69.

30 Heydenreich J, Kayser B, Schutz Y, *et al*. Total Energy Expenditure, Energy Intake, and Body Composition in Endurance Athletes Across the Training Season: A Systematic Review. *Sports Med Open* 2017;3:8.
31 Mountjoy M, Sundgot-Borgen JK, Burke LM, *et al*. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *Br J Sports Med* 2018;52:687–97.
32 King JA, Miyashita M, Wasse LK, *et al*. Influence of prolonged treadmill running on appetite, energy intake and circulating concentrations of acylated ghrelin. *Appetite* 2010;54:492–8.
33 Ghanbari-Niaki A. Ghrelin and glucoregulatory hormone responses to a single circuit resistance exercise in male college students. *Clin Biochem* 2006;39:966–70.
34 Broom DR, Miyashita M, Wasse LK, *et al*. Acute effect of exercise intensity and duration on acylated ghrelin and hunger in men. *J Endocrinol* 2017;232:411–22.
35 Espinoza García AS, Martínez Moreno AG, Reyes Castillo Z. The role of ghrelin and leptin in feeding behavior: Genetic and molecular evidence. *Endocrinol Diabet Nutr (Engl ed)* 2021;68:654–63.
36 Condo D, Lohman R, Kelly M, *et al*. Nutritional Intake, Sports Nutrition Knowledge and Energy Availability in Female Australian Rules Football Players. *Nutrients* 2019;11:971.
37 Holden SL, Forester BE, Keshock CM, *et al*. Sports Nutrition Knowledge of Volleyball Players. *Int J Kinesiol Higher Educ* 2019;3:58–65.
38 Gouttebarge V, Bindra A, Blauwet C, *et al*. International Olympic Committee (IOC) Sport Mental Health Assessment Tool 1 (SMHAT-1) and Sport Mental Health Recognition Tool 1 (SMHRT-1): towards better support of athletes' mental health. *Br J Sports Med* 2021;55:30–7.