doi:10.4085/1062-6050-0016.25

Title: Health-Related Quality of Life in Adolescent Athletes: Correlations with Energy Availability, Disordered Eating, and Compulsive Exercise Behaviors

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Acknowledgements: Funding for this study was provided by the University of Colorado/Children's Hospital Colorado Center for Children's Surgery Ponzio Research Accelerator Award.

Unrelated to this study, Dr. Howell has received research support from the Eunice Kennedy Shriver National Institute of Child Health & Human Development (R03HD094560,), the National Institute of Neurological Disorders And Stroke (R01NS100952, R43NS108823), the National Institute of Arthritis and Musculoskeletal and Skin Diseases (1R13AR080451), 59th Medical Wing Department of the Air Force, MINDSOURCE Brain Injury Network, and the Tai Foundation, and the Colorado Clinical and Translational Sciences Institute (UL1 TR002535-05). Dr. Armento has received funding from the National Center for Advancing Translational Sciences/Clinical and Translational Science Awards Program/Colorado Clinical and Translational Sciences Institute (K12 TR004412, UM1 TR004399).

Abbreviations: Health-related quality of life (HRQOL), relative energy deficiency in sport (REDs), Eating Disorder Examination Questionnaire (EDE-Q), Compulsive Exercise Test (CET), Pediatric Quality of Life Inventory (PedsQL), body mass index (BMI), dual energy x-ray absorptiometry (DXA), fat free mass (FFM)

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Abstract:

Context: Low energy availability, disordered eating, and/or compulsive exercise behaviors may negatively impact health-related quality of life (HRQOL), and this has not been studied specifically in adolescent athletes.

Objective: Assess the correlations of HRQOL with energy availability, disordered eating, and compulsive exercise in adolescent athletes.

Design: Cross-sectional

Setting: A single sports medicine center and local athletic partnerships

Participants: 13-18-year-old male and female athletes who were actively engaged in at least one organized sports team at the time of study participation

Main Outcome Measures: Participants completed the Pediatric Quality of Life Inventory (PedsQL), the Eating Disorder Examination Questionnaire (EDE-Q), the Compulsive Exercise Test (CET), and seven days of exercise monitoring (via wrist-worn heart rate activity monitor) and dietary intake reporting to assess energy availability.

Results: Sixty-four participants (n=39 female, mean age=15.5±1.5 years) completed the study. There were no significant associations between energy availability (β= -0.07, 95% CI= -0.32, 0.19, p= 0.56) or CET scores (β= -0.28, 95% CI= -1.28, 0.72, p= 0.58) and PedsQL scores, but there was a significant association between EDE-Q scores (β= -4.78, 95% CI= -8.53, -0.76, p= 0.01) and PedsQL scores, after adjusting for participant sex. We observed a significant association between female sex and lower PedsQL scores (β= -6.43, 95% CI= -12.1, -0.76, p= 0.03).

Conclusion: Adolescent athletes who reported more significant disordered eating behaviors demonstrated worse HRQOL. Female athletes reported worse HRQOL overall compared to the male athletes. This highlights the importance of screening and early intervention for disordered eating behaviors to prevent the potential negative impact on HRQOL, as well as the consideration of sex-specific differences regarding HRQOL in adolescent athletes.

Keywords: Health-related quality of life, disordered eating, compulsive exercise, energy availability, adolescent athlete

Abstract Word Count: 67

Manuscript Word Count: 3360

Key points:

1. More significant disordered eating behaviors, even at a subclinical level, were associated with worse health-related quality of life in male and female adolescent athletes.
2. Clinicians who work with adolescent athletes should be aware of the negative impact disordered eating can have on health-related quality of life, emphasizing the importance of screening and early intervention for disordered eating behaviors in athletes.

Introduction:

Health-related quality of life (HRQOL) includes the physical, social, and psychological domains that influence quality of life (QOL) relative to one's health.[1] HRQOL has become increasingly recognized as an important outcome used to measure overall pediatric well-being.[2] Adolescent athletes report better HRQOL than their non-athlete peers, likely secondary to the myriad physical and psychosocial benefits of regular physical activity and organized sport participation.[3] Despite these numerous benefits, adolescent athletes are at risk for the sequelae of low energy availability (i.e. inadequate caloric intake to support normal physiological functioning after accounting for energy expended through exercise) given their high levels of exercise energy expenditure and poor nutrition patterns that can lead to insufficient nutritional intake.[4] Low energy availability can lead to relative energy deficiency in sport (REDs), a condition which includes multiple negative effects on physical and psychological health and sports performance.[5] Despite the known health and performance impairments associated with low energy availability/REDs, the relationship between energy availability and HRQOL in adolescent athletes has not been examined.

Low energy availability and the risk of malnutrition can occur due to unintentional inadequate energy intake, disordered eating and/or compulsive exercise behaviors.[6] Disordered eating includes purposeful restrictive eating behaviors, pathogenic behaviors to control weight or shape, and preoccupation with food and/or one's body weight or shape.[7] Compulsive exercise includes driven exercise behaviors for the purpose of preventing or reducing distress that continue despite interference in daily routines, the presence of injury, or lack of enjoyment.[8] Disordered eating is associated with lower HRQOL in adolescents,[9] but this has not been assessed specifically among adolescent athletes, who may be more vulnerable to disordered eating behaviors than their non-athlete peers secondary to internal and external pressures of the sport environment.[10] Similarly, while more severe compulsive exercise behaviors correlate with lower HRQOL in adults,[11,12] this relationship has not been explored in the adolescent athlete population. Adolescent athletes face unique challenges, such as peer or coach pressures to fit an “ideal” body type, weight cycling, and pressure to optimize performance, which can put them more at risk for low energy availability, disordered eating, and compulsive exercise.[7,13] Understanding the associations of energy availability, disordered eating, and compulsive exercise behaviors with HRQOL is important for healthcare providers, coaches, and parents to better care for and support adolescent athletes. If HRQOL is lower in athletes with low energy availability, disordered eating, and/or compulsive exercise behaviors, we can tailor interventions to specifically address QOL concerns. While some of these associations have been studied in isolation,[4,6,9,11] no studies to date have integrated each of these elements into a single investigation. Therefore, the aims of this study were to assess the relationships of HRQOL with energy availability, disordered eating, and compulsive exercise in adolescent athletes. We hypothesized that lower energy availability, more disordered eating and compulsive exercise behaviors would be associated with lower HRQOL in male and female adolescent athletes.

Methods:

Study Participants:

We conducted a cross-sectional study of adolescent athletes who were recruited from a single sports medicine center, local high schools, club sport organizations, and community events. We included male and female participants ages 13-18 years old who were actively engaged in at least one organized sports team (e.g. high school team, club team, or recreation center league) at the time of study enrollment. We excluded those with an active or prior clinical eating disorder diagnosed by a healthcare professional, athletes currently under the care of a dietitian, and injured athletes not actively participating in their sport.

Study Procedures:

Local Institutional Review Board approval was obtained prior to study commencement. Written informed assent/consent was obtained from participants and their legal guardian if under the age of 18 years. At the initial assessment, participants completed a series of questionnaires including a health history, the Eating Disorder Examination Questionnaire (EDE-Q),[14] the Compulsive Exercise Test (CET),[15] and the Pediatric Quality of Life Inventory (PedsQL).[16] Sex was determined based on participant self-report as “male” or “female,” and gender identity information was not collected. Body mass index (BMI) was calculated from height and weight obtained at the visit. All participants completed a dual energy x-ray absorptiometry (DXA) scan of the total body to obtain body composition data.

Subsequently, participants underwent a one-week period of exercise monitoring via wrist-worn actigraphy as well as a dietary intake assessment. A trained research professional provided participants with a wrist-worn heart rate/activity monitor (Fitbit Inspire 2 device, FitBit, San Francisco, CA, USA) and assistance with setting up a nutrition tracking application on their smartphone (MyFitnessPal, Inc.). Instructions on how to record each exercise session with the wearable activity monitor and how to record dietary intake with the phone application were given. Adequate time was provided for questions/answers to ensure that the participant (and family) understood the reporting requirements and were able to complete them for the following week. Participants also were provided with a paper log to record exercise and dietary intake if the activity monitor and phone application were not functioning, not available for data collection, or per participant preference.

For seven consecutive days after the initial visit, all participants recorded each exercise session (via wrist-worn actigraphy, paper log, or both), and all dietary intake (via the phone application, paper log, or both). The research professional monitored the participants’ data records and provided reminders to complete data collection if missing data was noted in the applications at any point during the one-week monitoring period. Following this monitoring period, the participant and a parent met virtually with either the research professional and/or the consulting sports dietitian to review the data and ensure accuracy of the records. If participants used the paper logs in addition to the activity monitor and phone application to record data, the data from both sources was reconciled. The research team used the United States Department of Agriculture Five-Step Multiple Pass method and portion size guides to validate any unmeasured portions for dietary intake.[17] For exercise sessions not captured by the activity monitor (e.g. if the participant was required to remove the device for competition), metabolic equivalents were calculated based on exercise sessions recorded in the paper log. After verification of all data entries, daily energy intake and exercise energy expenditure were analyzed and subsequently used in energy availability calculations.

Outcomes Measures:

Disordered eating: The Eating Disorder Examination Questionnaire (EDE-Q) is a 36-item questionnaire used to aide in the diagnosis of eating disorders.[14] The questionnaire asks respondents to rate the frequency of disordered eating thoughts/attitudes in the prior 28 days on a 7-point scale from "No days" to "Every day," and the frequency of disordered eating behaviors (such as binging and purging) by self-reported number of episodes in the prior 28 days. There are four subscales: restraint, eating concern, shape concern, and weight concern. The global score is calculated by summing the subscale scores and dividing by four. Higher scores are indicative of more severe disordered eating behaviors (range 0-6). There are published normative EDE-Q scores for adolescent girls and boys.[18,19]

Compulsive exercise: The Compulsive Exercise Test (CET) is a 24-item questionnaire evaluating components of compulsive exercise behaviors, including the five subscales of avoidance and rule-driven behavior, weight-control exercise, mood improvement, lack of exercise enjoyment, and exercise rigidity. [15,20] It asks respondents to rate how much they relate to a statement on a 6-point scale from "Never" to "Always true." Subscale scores are obtained by taking the average of the sum of points within each subscale, and the total score is calculated as the sum of the mean score for each subscale. Higher scores reflect more severe compulsive exercise behaviors (range 0-25).[15]

Health-related quality of life: The Pediatric Quality of Life Inventory (PedsQL) is a 23-item questionnaire designed to evaluate HRQOL in children and adolescents by assessing physical, emotional, social, and school functioning domains.[2] The questionnaire includes statements about these topics, asking the respondents to rate how much they relate to each statement on a 5-point scale from "Never" to "Almost always." Items are reverse scored and then linearly transformed to a 0-100 scale. A higher total score reflects better HRQOL.[16] A psychosocial health summary score is calculated as the mean of the sums of the emotional, social, and school functioning scale scores, and a physical health summary score is the same as the physical functioning scale score.[21]

Energy availability: Energy availability was calculated for each participant using the equation: Energy availability = [energy intake (kcal) – exercise energy expenditure (kcal)] / fat free mass (kg).[5] Energy intake and exercise energy expenditure were quantified as described above. Fat free mass (FFM) was obtained from the total body DXA scan data. Daily energy availability was calculated and then averaged across the seven-day monitoring period for each participant.

Statistical Analysis:

Data are presented as mean (SD) for continuous variables and the number within group (corresponding percentage) for categorical variables. Descriptive statistics were performed to evaluate demographics, physical activity and nutrition characteristics, and questionnaire scores for the study sample. We used Pearson's R correlations to assess the relationships between PedsQL scores and energy availability, EDE-Q, and CET scores. We selected Pearson's r correlations because, given our sample size (n=64) and the Central Limit Theorem's assurance of normality in the sampling distribution,[22] we determined that Pearson's r was an appropriate and interpretable method for evaluating associations between continuous measures in this context. Correlations were considered low <0.39, moderate (±)0.4-0.59, moderately high (±)0.60-0.79, and high ≥(±)0.80. As a post-hoc analysis, we also assessed the correlation between EDE-Q and PedsQL psychosocial health summary scores and physical health summary scores. In addition, we constructed multivariable linear regression models to assess the association between energy availability, EDE-Q, and CET scores (predictors) with PedsQL scores (outcome), while adjusting for the effect of participant sex (covariate). We adjusted for participant sex because of past research suggesting that sex influences both our predictors and outcome of interest.[23,24,25,26] We performed standard linear regression diagnostics, including examining residual plots for linearity, homoscedasticity, and approximate normality to ensure the data conformed to regression assumptions. This included assessment of residual plots and computing adjusted R^2 to gauge generalizability. Additionally, we assessed multicollinearity via variance inflation factors (VIF), with all predictors exhibiting VIF <1.02, confirming minimal collinearity. Statistical significance was set at $\alpha = 0.05$. All analyses were two-sided and performed using Stata Statistical Software: Version 18 (StataCorp, LLC, College Station, TX, USA).

Results:

There were 65 participants from a variety of sports enrolled in the study, of which 64 completed the entire protocol (98% retention rate; 60% female participants, average age=15.5±1.5 years, Table 1). Sixty-five participants completed all questionnaires, but only 64 participants (25 males, 39 females) completed exercise and dietary intake data collection and were included in the final analysis. Table 1 outlines the exercise, energy intake, body composition, and energy availability data, as well as the average scores on the PedsQL, EDE-Q, and CET questionnaires among the male and female participants. We used established clinical cutoffs to categorize energy availability as low (< 30 kcal/kg FFM), subclinical (30-40 kcal/kg FFM/day in males, 30-45 kcal/kg FFM/day in females), and optimal (> 40 kcal/kg FFM/day in males, > 45 kcal/kg FFM/day in females).[27,28] Using these cutoffs, the proportion of female participants demonstrating low energy availability was 21%, subclinical was 49%, and optimal was 31%. For the male participants, 27% demonstrated low, 23% demonstrated subclinical, and 50% demonstrated optimal energy availability measurement.

There was no significant correlation found between PedsQL scores and energy availability (Pearson r = -0.11, p=0.39) or CET scores (Pearson r = -0.08, p=0.51). However, there was a low inverse correlation found between PedsQL and EDE-Q scores (Pearson r = -0.30, p=0.02). Furthermore, we identified a low correlation between EDE-Q scores and the PedsQL psychosocial health summary scores (Pearson r = -0.33, p =0.007), but a weak correlation between EDE-Q and the PedsQL physical health summary scores (Pearson r = -0.13, p=0.31).

Results from the multivariable linear regression models demonstrated no significant association of energy availability or CET scores with PedsQL scores, after adjusting for participant sex (Table 2). There was a significant association between higher EDE-Q scores and lower PedsQL scores, after adjusting for participant sex (Table 2). For every 1-point increase in EDE-Q score, the PedsQL score decreased by an average of 4.78 points, adjusting for the effect of participant sex. Across all models, we observed a significant association between female sex and lower PedsQL scores (Table 2).

Discussion:

Our data indicate that those with more significant disordered eating behaviors demonstrated lower HRQOL among both the male and female athletes, while HRQOL was not significantly associated with energy availability or compulsive exercise behaviors. The female athletes reported lower HRQOL overall than the male athletes in our sample.

The finding of an inverse correlation between disordered eating behaviors and HRQOL aligns with what has been previously reported in the literature in non-athlete populations. A recent systematic review and meta-analysis demonstrated that disordered eating behaviors and attitudes were associated with impaired HRQOL in children and adolescents from school- or community-based studies (vs. study samples with specific disease conditions such as obesity).[9] To our knowledge, there are no other published studies examining this relationship specifically in the adolescent athlete population. It has been shown that the minimal clinically important difference (MCID) for PedsQL total score is a 4.36 point change.[16] The MCID is defined as the smallest difference in a score of a domain of interest that patients perceive to be beneficial and that would direct a change in the patient's management.[16] We found an average 4.78 point decrease in PedsQL score for every 1 point increase in EDE-Q score among our study sample, after adjusting for participant sex. This suggests that more disordered eating behaviors (i.e. increase in 1 point or more on the EDE-Q) are associated with a reduction of self-reported HRQOL (i.e. a 4.78-point decrease on the PedsQL) exceeding the established MCID value and thus, representing a change that would likely be perceived as meaningful to the patient and treating healthcare professional. Disordered eating may contribute to lower HRQOL in adolescents through its interference with social functioning, academic functioning, and sustaining peer relationships.[29,30,31,32] This is supported by our finding of a low, significant correlation between EDE-Q and the PedsQL psychosocial health summary scores, which reflects emotional, social, and school functioning. Furthermore, there are many psychological risk factors (e.g. body dissatisfaction, low self-esteem, perfectionism) and sociocultural factors (e.g. peer, coach, and media pressures, weight stigma) associated with disordered eating in athletes,[7] and the presence of these factors may also influence/reduce HRQOL. Future studies should examine the various mediators that may exist in the relationship between disordered eating and HRQOL in the young athlete population.

Disordered eating can be conceptualized on a continuum, with the progression to a clinical eating disorder (e.g. anorexia nervosa) on the most severe end of the spectrum.[33] It is important to consider the severity of disordered eating behaviors in our study sample. Using normative values for EDE-Q scores in adolescent girls[18] and adolescent boys,[19] the average global score for the female athletes was below average, but was above average for the male athletes, in our sample. Despite these differences, the association between more severe disordered eating behaviors and reduced HRQOL persisted after adjusting for sex. Generally, subscale or global scores of 4 or higher indicate greatest risk for a clinical eating disorder.[18] While no one in our sample reached this threshold, we still found an association between lower HRQOL and subclinical disordered eating behaviors. These findings are informative for clinicians who should not underestimate the impact of even mild or subclinical disordered eating behaviors on HRQOL in both male and female adolescent athletes. It also highlights the importance of screening for disordered eating and providing nutrition and mental health resources if these behaviors are identified, while emphasizing support for the potential negative consequences on HRQOL in these athletes. Optimizing HRQOL could include support in navigating difficulties with activities of daily living and school functioning, challenges with peer relationships, and processing emotions.

We did not observe a significant correlation between HRQOL and energy availability. We recognize there are inherent limitations in measuring energy availability outside of a laboratory,[34] and methodological limitations could have influenced our findings. Our study participants reported lower energy intakes compared to calculated estimated energy requirements using the National Academies' equations,[35] suggesting possible under-reporting of energy intake despite our careful efforts to ensure accuracy through our methodology. Further discussion of the study findings related to energy availability have been published elsewhere.[36] Keeping in mind that under-reporting of dietary intake may have led to inaccurately low energy availability measurements, those with lower energy availability in our sample did not report lower HRQOL. It would be expected that those experiencing the physiological, psychological, and/or performance impairments accompanying low energy availability (as described in the REDs model)[5] would lead to worse HRQOL. However, we did not directly examine signs or symptoms of low energy availability (e.g. gastrointestinal distress, sleep disturbance, decreased training response and recovery) in our study. Future research should include the assessment of symptomatology of low energy availability and its influence on HRQOL in athletes.

Our results did not support our hypothesis that more compulsive exercise behaviors would be associated with worse HRQOL. One possible explanation is that the CET scores for our sample were relatively low and may not have been severe enough to influence HRQOL. Compulsive exercise is associated with poor HRQOL in adults with eating disorders.[37,38] Additionally, one study of adult recreational exercisers and athletes found more compulsive exercise behaviors correlated with higher levels of anxiety, depression, and stress and lower self-esteem and life satisfaction, even after adjusting for eating disorder symptoms.[11] Other studies have shown compulsive exercise is associated with increased risk of injury, social impairment, and depression,[12] all of which could impair HRQOL. However, a study of adults who were considered exercise-addicted (based on the Exercise Addiction Inventory) showed no significant difference in HRQOL compared to the control group.[39] More research is needed to better understand the relationship of compulsive exercise and HRQOL in adolescent athletes, who may be vulnerable to develop compulsive exercise behaviors due to pressures to perform in their sport.

Female athletes demonstrated lower HRQOL than male athletes in our sample, which is consistent with what has been previously reported in the literature. Female adolescents (not specifically athletes) demonstrated poorer HRQOL, worse life satisfaction, and more psychological distress than male adolescents,[40,41] and similar findings also were noted among adolescent athlete populations.[23,3] While athletes generally report better HRQOL than nonathletes,[3] clinicians, coaches, and parents should recognize that female athletes may be more at risk for lower HRQOL than their male athlete peers.

Our study had several limitations. As noted above, the methodological limitations of energy available measurement should be considered. We attempted to address potential inaccuracies in energy availability measurement by having multiple data sources of dietary and exercise data collection (paper and electronic records) for each participant, sending regular reminders to participants to complete data collection, and verification of the data at the conclusion of the monitoring period via interview with the research team. Other limitations include the biases associated with self-report questionnaires,[42] as well as the fact that the EDE-Q and CET are not specific to athlete populations (although they are commonly accepted and used in athletes).[13,43] Finally, our findings may not be generalizable to other populations outside of the single geographic area in which the study was conducted, or to non-athlete populations as there was no control group of adolescents who were not participating in organized sports included. Additionally, a large proportion of the participants in our study were soccer athletes, and sport type may have influenced the results.

In summary, the findings of our study demonstrated that worse HRQOL, particularly in the psychosocial domain, was significantly associated with more severe disordered eating behaviors in adolescent athletes. However, we did not find significant associations with HRQOL and energy availability or compulsive exercise behaviors. Additionally, our data supports the existing research showing that female adolescent athletes have worse HRQOL compared to their male athlete peers. Clinicians, coaches, and parents should be aware of the negative impact disordered eating, even at a subclinical level, can have on HRQOL, emphasizing the importance of screening and early intervention for disordered eating behaviors and efforts to optimize HRQOL in adolescent athletes.

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Table 1. Demographics, health history, physical activity, and questionnaire scores of male and female athlete groups. Continuous variables are represented as mean (SD), and categorical variables are presented as n (%).

Variable		Male Participants (n=26)[a]	Female Participants (n=39)[a]
Age (years)		15.3 (1.3)	15.6 (1.6)
Race	American Indian or Alaska Native Asian	2 (8%)	0 (0%)
	Black or African-American	1 (4%)	1 (3%)
	Native Hawaiian or Pacific Islander	0 (0%)	1 (3%)
	White	24 (92%)	34 (87%)
	Unknown or not reported	0 (0%)	4 (10%)
Ethnicity	Hispanic or Latino/a	4 (15%)	9 (23%)
	Not Hispanic or Latino/a	21 (81%)	27 (93%)
	Unknown or not reported	1 (4%)	3 (8%)
Height (cm)		172.6 (9.0)	164.4 (6.5)
Weight (kg)		61.2 (13.7)	54.9 (8.8)
BMI (kg/m^2)		20.7 (3.7)	20.4 (2.9)
Sex-specific BMI-for-age percentile		47.0 (27.2)	45.7 (23.5)
Primary sport	Soccer	9 (35%)	16 (41%)
	Football	3 (12%)	0 (0%)
	Volleyball	0 (0%)	6 (15%)
	Baseball/softball	3 (12%)	1 (3%)
	Basketball	2 (8%)	0 (0%)
	Swimming/diving	3 (12%)	1 (3%)
	Cross Country	1 (4%)	6 (15%)
	Track and Field[b]	2 (8%)	2 (5%)
	Dance	0 (0%)	3 (8%)
	Lacrosse	2 (8%)	0 (0%)
	Tennis	0 (0%)	1 (3%)
	Ice Hockey	0 (0%)	1 (3%)
	None listed[c]	1 (4%)	2 (5%)
Moderate-to-Vigorous Physical Activity (Minutes/Day)		71.4 (35.2)	61.8 (37.4)
Light Physical Activity (Minutes/Day)		227.7 (60.9)	263.5 (51.6)
Step count (mean steps/day)		10,429 (3,694)	10,631 (3,799)
Mean daily exercise energy expenditure (kcal/d)		562.9 (296.1)	435.0 (228.2)
Body fat percentage		20.6 (6.8)%	28.0 (6.2)%
Fat free mass (kg)		46.5 (13.9)	38.7 (5.4)
Mean daily energy intake (mean calories consumed/day)		2277 (437)	2001 (405)
Energy availability (kcal/kg-FFM/day)		36.0 (12.4)	40.4 (12.2)
Global EDE-Q score		0.7 (0.8)	0.7 (0.7)
Total CET score		10.7 (3.2)	11.1 (2.8)
PedsQL score		87.7 (10.6)	81.2 (12.4)

[a] N=65 participants completed all questionnaires, but only 64 participants (25 males, 39 females) completed the full protocol.
[b] Including all running and field events
[c] Did not select a primary sport but was still active in an organized sport

Table 2. Multivariable linear regression results describing the association between predictor variables and PedsQL while adjusting for sex. β coefficients provided are non-standardized.

Model 1	**β coefficient**	**95% Confidence Interval**	**P value**
Energy availability	-0.07	-0.32, 0.18	0.56
Sex	-6.23	-12.4, -0.10	0.04
Model 2	**β coefficient**	**95% Confidence Interval**	**P value**
EDEQ score	-4.78	-8.53, -1.03	0.01
Sex	-6.43	-12.11, -0.76	0.03
Model 3	**β coefficient**	**95% Confidence Interval**	**P value**
CET score	-0.28	-1.28, 0.72	0.58
Sex	-6.34	-12.30, -0.38	0.04