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Original Research

Health of Collegiate Athletes - An Investigation into Symptoms Associated with Low Energy Availability

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Abstract

International Journal of Exercise Science 19(2): 2016, 2026. Chronic low energy availability (LEA) describes inadequate energy intake relative to expenditure and underlies Relative Energy Deficiency in Sport (REDs), impairing physiological health and athletic performance. This study examined relationships between both anthropometry and body composition, cardiovascular function, and sleep quality in collegiate athletes with LEA-associated symptoms. A total of 109 collegiate athletes (Males = 43, females = 66) underwent anthropometric analysis (BOD POD), resting cardiovascular assessment, and Pittsburgh Sleep Quality Index (PSQI) questionnaire. Mann-Whitney U-tests assessed sex differences in cardiovascular function, anthropometry, and sleep quality. Spearman rank correlations (ρ) evaluated associations between anthropometric indices and cardiovascular and sleep outcomes. Males exhibited greater anthropometric measures ($p < 0.01$) and blood pressure ($p < 0.001$) than females. Global PSQI scores indicated poor sleep quality in both sexes (males: 5.9 ± 2.7; females: 5.7 ± 2.4), with no significant sex differences. In females, anthropometry was positively correlated with blood pressure ($p < 0.01$). In males, greater anthropometric measures were positively associated with blood pressure and resting heart rate ($p < 0.05$). Of the population studied, 19% of males and 29% of females presented with a clinically low %BF; 49% of males and 47% of females had bradycardia; 16% of males and 55% of females had hypotension; and 67% of males and 62% of females had poor sleep quality. Symptoms associated with LEA are prevalent in male and female collegiate athletes and suggest the need for closer monitoring to ensure athletes optimal health and performance.

Keywords: Sport Science; anthropometry, cardiovascular function, sleep, student athletes

Introduction

Relative Energy Deficiency in Sport (REDs) is a term defined as chronic low energy availability (LEA),[1] a state where the body experiences prolonged (weeks – months) energy deficit.[2] LEA can manifest due to inadvertent or planned reduction in energy intake that is insufficient to support physiological demands.[3] Symptoms associated with chronic low energy intake include decreased metabolism, impaired reproductive/hormonal function, compromised bone health, impaired cardiovascular functioning, and decreased immunity.[4] Poor sleep quality and psychological health disorders (anxiety, depression, and disordered eating behavior) are also commonly associated with REDs.[5] The development of LEA is in direct relation to the amount of fat-free mass of an athlete[1]. Different sports have different anthropometric requirements that should be considered on an individual basis.[6] Nevertheless, adipose tissue is a vital endocrine organ.[7] 17% body fat (BF) in females has been stated as critical for achieving menstrual function.[8] The

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current consensus towards establishing a healthy %BF for male's ranges from 10-22% and 20-32% for females.[9] However, it is important to note athletes may exist above or below these normative values. University athletes are often thought to have superior health to their non-athletic peers.[10] However, when intense exercise routines are coupled with inadequate energy intake, as in the case chronic LEA, the potential of developing cardiovascular complications increases.[11] Bradycardia and hypotension have been associated with chronic to LEA.[12] Hypotension caused by autonomic dysfunction can lead to deleterious performance and health outcomes for exercising individuals.[13] Bradycardia below normal training adaptation is associated with chronic LEA.[2] Furthermore, an athlete's Blood pressure (BP) and mean arterial pressure (MAP) provide insight into an athlete's cardiovascular function. MAP is the product of cardiac output and systemic vascular resistance, which are modulated by other variables imperative to health.[14] Moreover, the underlying etiology of both REDs and Over training Syndrome is LEA.[3] This relationship has provoked further investigation into aspects of the cardio autonomic response. Heart rate variability (HRV) can provide valuable insight into how athletes manage exercise stress in addition to other psychophysiological strain.[15] Furthermore, sleep is a critical component of recovery and athletic performance for athletes, a decreased sleep quality can lead to psychological and physiological disturbances that negatively impact performance.[16] Sleep disturbance in athletes is a common indicator of REDs, along with increased risk of depression and anxiety.[17] Chronic LEA, and the individual or synergistic manifestation of the aforementioned symptoms can lead to performance decrements. Moreover development of these symptoms can increase athletes' risk of injury and health problems.[4] Subtle symptomology may lead medical practitioners to identify differential diagnoses before addressing an athlete's energy availability needs.[5] Thus, it can be challenging to accurately diagnose LEA promptly. Also, the limited use of standardized risk assessment protocols, makes it difficult to discern the true risk of LEA within university athlete populations.[11] The current study aimed to identify relationships between indices of anthropometry (height, weight and BMI), and body composition (body fat and fat free mass), and both cardiovascular function and sleep quality within a colligate athletes as these indices can be revealing into symptoms associated with LEA and or REDs. Additionally, the study seeks to quantify the number of athletes that present with at least one clinically associated symptom. Assessing body composition, cardiovascular function and sleep quality offers coaches and practitioners' field-based monitoring techniques.

Methods

Participants

A sample size of ≥89 participants was determined to be acceptable when using a computer software program (G*Power 3.1) that incorporated the conventional α error probability of 0.05 and a power of (1-β error probability) 0.85 and sleep quality in female varsity soccer players.[18] The effect size was revealed to be 0.27. A total of 109 student athletes (male = 43 | female = 66) from a Canadian University provided written informed consent. The investigation was approved by and followed the recommendations of the institutions Research Ethics Board, and all procedures were conducted in accordance with the ethical standards set by the Helsinki Declaration. Participants must have been an active member of the university's varsity team. Athletes were recruited from five varsity athletic teams: Men's and Women's Soccer, Men's and Women's Volleyball, Cross Country & Track and Field, Women's Hockey, and Women's Basketball, and they had the opportunity to self-identify. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science.*[19] Data was collected by investigators in a private and inclusive laboratory. Participants engaged in a single testing assessment for the purpose of data collection.

Protocol

Anthropometry and Body Composition.

Participants' height and weight was measured using a wall mounted stadiometer (Health o meter Stadiometers) and weight was recorded using a properly celebrated digital scale (COSMED, Concord, CA) connected to the BOD POD®. Participant's body composition was assessed using air displacement plethysmography. The two-compartment model offered measurements of Fat Mass (FM Kg), Fat Free Mass (FFM kg) and total body mass (kg), it also provided %BF and %FFM. It was recommended that participants followed the manufacture pre-test protocol refraining from intense exercise, food, and drink at least two hours prior to their assessment time. However, findings from Perrotta et al, suggest when negating pretest guidelines, results from the BOD POD® (COSMED, Concord, CA) remains statistically reliable[20]. Therefore, these pre-test guidelines were not strictly enforced due to the difficultly of controlling participant behaviour prior to the assessments. Participants followed the appropriate testing protocol as per the manufactures instruction; all jewelry removed, wearing spandex shorts and a sports bra (females), and spandex bottom or a speedo (males). A swim cap was worn to contain head hair. Results were referenced with clinically established %BF cut off for males (< 6%) and females (< 17%).[8,9]

Resting Cardiovascular Function.

After completing the BOD POD®, a resting cardiovascular assessment was performed. Participants were fitted with a Polar H10 (Polar Electro Oy, Kempele, Finland) chest strap heart rate monitor, equipped to sample at 1000Hz. They were then instructed to lay supine with their arms and legs uncrossed, breathing normally for a ten-minute stabilization period. After eight minutes, resting heart rate (HR) and HRV were measured using the validated smartphone application Elite HRV[21] connected via Bluetooth® to the Polar H10 HR monitor. Resting HR was recorded in beats per minute (bpm), the square root of the mean squared differences of successive R–R intervals (rMSSD) was selected as the variable of interest based on its validity to represent cardiac vagal modulation, and when not accounting for menstrual cycle phase or oral contraceptive usage.[22] rMSSD is also less affected by respiration and can reliably reflect short-term HRV[23]. After the HR and HRV recording participants remained supine for a BP measurement. Using an automatic sphygmomanometer (Connex® ProBP™ 3400 Digital Blood Pressure Device), systolic and diastolic BPs, as well as map were recorded in milligrams of mercury (mmHg). All recordings were taken from the left arm using an appropriately sized cuff positioned three centimeters above participants' antecubital space. Pulse pressure (PP) was determined as the absolute value difference between the end diastolic pressure and end systolic pressure (mmHg). Bradycardia was defined as a resting HR < 60 bpm[17] and hypotension was defined as systolic BP ≤ 110 mmHg or diastolic BP ≤ 60 mmHg.[24] Normal blood pressure for both males and females is defined by the *American Heart Association* is ≤ 120 mmHg systolic or BP ≤ 80 mmHg diastolic, anything above this typical guideline is considered elevated or Hypertensive.[25]

Sleep Quality.

Following the anthropometric and resting cardiovascular assessment, participants were asked to complete the Pittsburgh Sleep Quality Index (PSQI). The PSQI was selected as a valid instrument to assess the sleep quality and disturbance in participants. The PSQI has strong utility and reliability in identifying sleep disturbance using post hoc justification and comparative analysis with polysomnography.[26] Participants were informed that this is a brief questionnaire asking them to generally reflect on their sleep over the past month (non-inclusive of the month in which the questionnaire was administered in). They were provided with a physical copy of the sleep quality questionnaire to complete and it was requested that they answer all questions honestly and request clarification regarding an item if unsure. The PSQI is a seven-component questionnaire that scores respondents on subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, medication use, and daytime dysfunction[26]. Total sleep disturbance was calculated as per the PSQI scoring[25]. A PSQI global score of ≥ 5 was deemed clinically significant for poor.[26]

Statistical Analysis

Statistical analysis was performed using JASP computer software (Version 0.19.3). Multiple data sets were identified to be non-normally distributed after using a Shapiro-Wilk test ($p < 0.05$). As such, non-parametric analyses were utilized for statistical analysis. Descriptive statistics were used to summarize anthropometric measurements, resting cardiovascular function, and sleep quality in all participants. A Mann-Whitney U Test was used to assess for statistical differences in cardiovascular function, anthropometry, and sleep quality between sexes (Figure 1). A Spearman Rank Correlation coefficient (ρ) was utilized to examine the strength of association between indices of anthropometry and body composition and both cardiovascular function and sleep quality. The strength of correlation was establish using the following guidelines: $\rho = 0.10 – 0.29$ small, $\rho = 0.30 – 0.49$ moderate, and $\rho > 0.50$ large[27]. Athletes who displayed clinical symptoms of LEA are provided as a percentage of the total sample examined. Significance was declared as $p < 0.05$.

Results

Descriptive statistics displaying differences between sexes in anthropometry, cardiovascular function, and sleep quality, are shown in Table 1 and Table 2. A Mann Whitney U test was performed to compare measured values between the male and female groups for both anthropometric indicis, cardiovascular function, and sleep quality. In all cases of anthropometric and body composition measures males significantly differed compared to females; greater weight, height, BMI, FFM, and lower FM (Table 1). For Cardiovascular function it was found that HR, and diastolic BP were not significantly different between sexes, this is likely attributed to a high level of variance within the data. The association between anthropometry, cardiovascular function, and sleep quality, for both males (Table 4) and females (Table 3) are displayed as a correlation matrix with its corresponding p-value. PSQI scores in females displayed an inverse association with diastolic BP ($\rho = 0.24$, $p = 0.05$). Males displayed clinical symptoms of LEA are shown in Table 4, there a positive association between PSQI scores and FFM ($\rho = 0.36$, $p = 0.02$), weight ($\rho = 0.50$, p = 147 $5.82×10-4$), and height ($\rho = 0.56$, $p =7.95×10-5$). The percentage of males and females displaying clinical symptoms of LEA is shown in Figure 1.

Table 1. Descriptive statistics of anthropometric and body composition measures for male and female collegiate athlete samples.

	n	Weight (kg)	Height (cm)	BMI (kg/m^2)	FFM (kg)	FFM (%)	BF (Kg)	BF (%)
Male	43	80.9±11.1***	181.4±11.4***	24.7±3.5*	72.2±8.5***	89.55±4.9***	8.70±5.03***	10.44±4.9***
Female	66	67.2±10.2	170.5±7.1	23.05±2.6	53.7±6.7	80.35±6.1	13.54±5.96	19.65±6.1

Values are displayed as mean (±SD) *p < 0.05 **p <0.001 ***p<0.0001
Note males significantly differ compared to females

Table 2. Descriptive statistics of cardiovascular measures and sleep quality for male and female collegiate athlete samples.

	n	**RHR (bpm)**	**rMSSD (ms)**	**SBP (mmHg)**	**DBP (mmHg)**	**MAP (mmHg)**	**PP (mmHg)**	**PSQI (Global)**
Male	43	62.0±12.4	70.2±39.6	123.5±11.2***	66.0±5.8	85.2±7.0***	57.4±8.9***	5.9±2.7
Female	66	60.9±9.8	79.4±40.6	109.2±8.1	65.6±5.9	79.8±5.9	43.6±6.5	5.7±2.4

Values are displayed as mean (±SD) *p < 0.05 **p <0.001 ***p<0.0001

Note males significantly differ compared to females

Table 3. Spearman correlation matrix showing associations between anthropometry (BMI, height and weight) and body composition (FFM and %BF), blood pressure indices (PP, MAP, SBP, DBP), heart rate metrics (RHR, rMSSD), and global PSQI score in female varsity athletes (ρ values and p-values displayed).

Variable		BMI (Kg/m²)	FFM (kg)	BF (%)	Weight (Kg)	Height (cm)	PP (mmHg)	RHR (bpm)	rMSSD (ms)	MAP (mmHg)	SBP (mmHg)	DBP (mmHg)	PSQI (global)
BMI	Spearman's	-											
	P-value												
FFM	Spearman's	0.66***	-										
	P-value	2.22×10-9											
FM	Spearman's	0.45***	0.06	-									
	P-value	1.35×10-4	0.61										
Weight	Spearman's	0.82***	0.87***	0.50***	-								
	P-value	2.06×10-17	6.67×10-21	1.77×10-5									
Height	Spearman's	0.19	0.68***	0.28*	0.66**	-							
	P-value	0.13	4.45×10-10	0.02	1.73×10-9								
PP	Spearman's	0.38*	0.40***	0.19	0.44***	0.27*	-						
	P-value	1.58×10-3	8.69×10-4	0.12	2.31×10-4	0.03							
RHR	Spearman's	-0.16	-0.03	-0.12	-0.08	0.12	0.03	-					
	P-value	0.20	0.80	0.35	0.53	0.35	0.79						
rMSSD	Spearman's	0.06	0.09	-0.11	0.04	0.04	0.01	-0.52**	-				
	P-value	0.65	0.49	0.36	0.75	0.85	0.92	7.44×10-6					
MAP	Spearman's	0.16	0.32**	0.14	0.29*	0.34**	0.20	0.06	-0.04	-			
	P-value	0.21	8.51×10-3	0.28	0.02	5.60×10-3	0.11	0.61	0.78				
SBP	Spearman's	0.34**	0.47***	0.18	0.47***	0.40***	0.72***	0.16	-0.05	0.76***	-		
	P-value	5.26×10-3	7.28×10-5	0.14	8.33×10-5	9.44×10-4	5.89×10-12	0.21	0.72	1.57×10-13			
DBP	Spearman's	0.02	0.17	0.07	0.14	0.26*	-0.05	0.15	-0.07	0.88***	0.61***	-	
	P-value	0.85	0.17	0.59	0.25	0.03	0.66	0.20	0.57	1.17×10-22	4.97×10-8		
PSQI	Spearman's	-0.11	-0.11	0.03	-0.09	-0.04	0.09	-0.11	0.09	-0.10	-0.12	-0.24	-
	P-value	0.38	0.45	0.78	0.45	0.76	0.47	0.38	0.49	0.45	0.35	0.05	

Table 4. Spearman correlation matrix showing associations between anthropometry (BMI, height and weight) and body composition (FFM and %BF), blood pressure indices (PP, MAP, SBP, DBP), heart rate metrics (RHR, rMSSD), and global PSQI score in male varsity athletes (ρ values and p-values displayed)

*p < .05, ** p < .01, *** p < .001

Variable		BMI (Kg/m²)	FFM (kg)	BF (%)	Weight (Kg)	Height (cm)	PP (mmHg)	RHR (bpm)	rMSSD (ms)	MAP (mmHg)	SBP (mmHg)	DBP (mmHg)	PSQI (global)
BMI	Spearman's	-											
	P-value												
FFM	Spearman's	0.58***	-										
	P-value	5.17×10-5											
FM	Spearman's	0.10	-0.12	-									
	P-value	0.51	0.46										
Weight	Spearman's	0.53***	0.89***	0.26	-								
	P-value	2.99x10-4	1.07x10-15	0.10									
Height	Spearman's	-0.33*	0.44**	0.17	0.50***	-							
	P-value	0.03	7.97×10^{-3}	0.27	5.54x10-4								
PP	Spearman's	0.23	0.08	0.35*	0.17	-5.67x10-4	-						
	P-value	0.13	0.61	0.02	0.27	1.00							
RHR	Spearman's	0.38*	0.27	0.16	0.31*	-0.14	0.28	-					
	P-value	0.01	0.08	0.32	0.04	0.37	0.07						
rMSSD	Spearman's	0.11	0.26	0.02	0.28	0.11	-0.23	-0.37*	-				
	P-value	0.47	0.09	0.88	0.07	0.47	0.14	0.01					
MAP	Spearman's	0.30	0.10	0.21	0.18	-0.09	0.54***	0.34*	-0.22	-			
	P-value	0.05	0.51	0.18	0.26	0.56	2.19x10-4	0.02	0.16				
SBP	Spearman's	0.31*	0.09	0.33*	0.18	-0.07	0.86***	0.33*	-0.21	0.87***	-		
	P-value	0.04	0.58	0.03	0.24	0.65	2.23x10-13	0.03	0.18	1.93x10-14			
DBP	Spearman's	0.23	0.04	0.11	0.09	-0.14	0.10	0.35*	-0.15	0.86***	0.55***	-	
	P-value	0.14	0.80	0.46	0.56	0.36	0.51	0.02	0.33	1.68x10-13	1.22x10-4		
PSQI	Spearman's	-0.04	0.36*	0.16	0.50***	0.56***	-0.13	0.23	0.19	0.12	-2.06x10-13	0.25	-
	P-value	0.78	0.02	0.29	5.82×10^{-4}	7.95×10^{-5}	0.41	0.15	0.23	0.45	0.99	0.11	

*p < .05, ** p < .01, *** p < .001

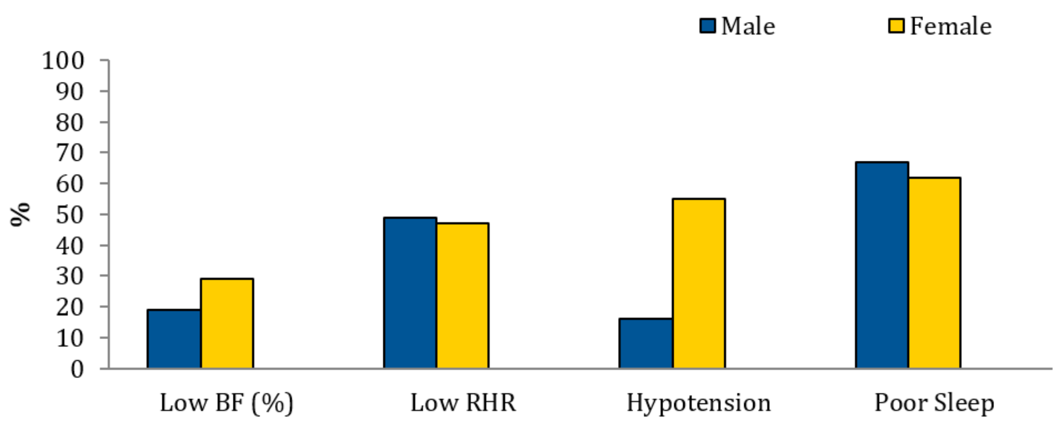

Figure 1. The percentage of male and female athletes that presented with a clinically identified criteria of LEA.

Discussion

This study sought to investigate the relationship between anthropometric and body composition indices (BMI, height, weight and %BF, FFM,) and both cardiovascular function and sleep quality in collegiate athletes, as well as assess symptoms associated with LEA. Using a sample of male and females across various sporting disciplines, a significant association between anthropometry and body composition and both cardiovascular function and sleep quality was found. Males had significantly different anthropometric measurements and BP recordings compared to females. A significantly higher percentage of females displayed a critically low %BF compared to males. Significant differences in male and female anthropometry and body composition can be attributed to physiological sex difference such as increased testosterone in males linked to increased production of growth hormone.[28] Therefore, it is expected that male athletes are larger individuals with increased FFM and decreased %BF compared to their female counterparts. Increased body size, as seen in male athletes, is correlated with an increased presence of androgens that can result in higher BP.[28] Additionally, different sports require different anthropometric qualities to meet unique event specific and positional demands.[6]

Male and female athletes displayed poor sleep quality (PSQI Global score >5). Reduced sleep quality in athletes may be attributed to poor sleep hygiene, diet, training intensity and external stresses.[16] Future studies would benefit from investigation into both athletes' dietary habits, sleep hygiene, and training load to develop a more comprehensive understanding of why they may be experiencing poor sleep. Unfavorable anthropometry in excessively high BF or dangerously low FFM, has been found to have a relationship between stress and recovery.[29] About two thirds of both males and female athletes in this study reported poor sleep quality (Figure 1). Sleep quality tends to be reflective of training intensity and recovery.[17] Previous studies have demonstrated similar findings, such that in athletes poor sleep quality is highly prevalent.[30] A significant relationship between anthropometric measures and both cardiovascular function and sleep quality was found in females. Lean body mass (FFM) has been shown to have positive significant associations with BP.[31] The results show that a significantly greater proportion of females presented with a low %BF compared to males (Figure 1). Additionally, diastolic BP was found to be negatively associated with PSQI. Previous studies have found inverse relationships with Diastolic BP and PSQI scores in collegiate athletes. BP influences tissue perfusion: essential for regulating organ homeostasis and is largely controlled through circadian mechanisms.[32] In both male and females there are significant correlations between FFM and BMI, and between weight and Height. BMI is directly derived as a proportion of weight (kg) and height (m^2).[33]

Moreover, FFM has been seen to increase with BMI. It is important to consider that sex and age both influence the relationship between FFM and BMI[33]. An inverse relationship between HR and HRV found in both male and females agrees with literature, such that high HR tends to have larger R-R intervals resulting in low HRV while the opposite is true for lower HR.[34] Figure 1 demonstrates the percentage of males and females that present with clinically significant indicators of LEA. There was a significantly higher percentage of females that presented with a low %BF compared to males. Athletes experience internal and external pressures to achieve certain physiques, it is reported that females tend to engage in behaviours that may increase their risk for LEA and a low %BF.[5] The larger percentage of females displaying hypotension and low %BF may indicate a higher risk of LEA.[2]

Extreme bradycardia and hypotension have been noted as symptoms associated with LEA.[2] Approximately half of the male (48%) and female (49%) athletes in this study presented with bradycardia, and just over half of the females (55%) presented with hypotension. Regular physical activity can lead to positive cardiovascular adaptations such as increased cardiac output and stroke volume along with decreased BP and resting HR.[10] Due to the athletic cohort in this study, it cannot be ruled out that the athlete's heart mechanism may be in occurrence. Conversely, excessive exercise and inadequate energy availability can lead to poor cardiovascular health such as hypotension and bradycardia.[35]

The purpose of this study was to investigate the relationship between anthropometry and body composition and both cardiovascular function and sleep quality in Collegiate varsity athletes. Secondarily, this study sought to understand the proportion of athletes who present with symptoms associated with LEA. It was found that indices of body composition (BMI, FFM, and %BF) were significantly correlated to both cardiovascular function and sleep quality. Additionally, each sport has unique body composition and proportional demands required for individual success. Thus, the relationships between anthropometry and cardiovascular function differed across sport and sexes. Moreover, there was a significantly higher percentage of female athletes that presented with a clinically low %BF and hypotension compared to male athletes. A third of both male and female athletes displayed at least one symptom associated with LEA. These findings demonstrate the importance of monitoring the health of varsity athletes. Future studies could focus on incorporating more comprehensive assessments for assessing overall health of varsity athletes. Furthermore, using clinically validated questionnaires such as the LEAF-Q or LEAM-Q could provide more information regarding energy status and physiological function of athletes. In summary this study highlights the immense need for further investigation into the health status of varsity athletes. As well as the crucial importance of collaboration between athletes, coaches, and support staff to ensure optimal health and performance.

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