Research Article

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A Correlation between Relative Energy Deficiency-Sports, Bone Mineral Density & Sleep on Vertical Jump Performance of Male Team Sports Athletes

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ABSTRACT

Background: *Explosive movements like vertical jumping are critical in sports and influenced by physiological factors like energy availability, bone mineral density (BMD), and sleep quality.*

Objective*: To examine the correlation between relative energy deficiency, BMD, and sleep quality on vertical jump performance in male team athletes.*

Method: *64 male athletes were assessed for BMD using DEXA scans, energy availability via the LEAM-Q questionnaire, sleep quality using Pittsburgh Sleep Quality Index (PSQI), and vertical jump height as the outcome measure.*

Results: *BMD positively correlated with jump height ($r=0.385$, $p=0.002$), while LEA negatively correlated with both BMD ($r=-0.455$, $p<0.001$) and jump height ($r=-0.277$, $p = 0.027$). Sleep quality was associated with BMD and LEA but not with jump height*

Conclusion: *Higher BMD improves explosive power; LEA reduces BMD and jump performance. Optimizing energy intake and bone health aids performance and prevents injury.*

Keywords
Low energy availability, Body composition, Power, Recovery, Bone health.

Introduction
Achieving peak performance in team sports goes beyond training; it requires optimal physiological function, including energy balance, bone health, and recovery. Low Energy Availability (LEA), assessed using the low energy availability in male's questionnaire (LEAM-Q), occurs when an athlete's energy intake is insufficient to meet the body's demands after exercise. LEA negatively impacts metabolic function, immune health, cardiovascular efficiency, and bone health [1]. It contributes to Relative Energy Deficiency in Sport (RED-S), a syndrome recognized by the International Olympic Committee (IOC) in 2014 [1], highlighting the broad consequences of energy imbalance on performance and well-being.

One major effect of LEA is reduced bone mineral density (BMD), critical for withstanding high-impact sports. Sports involving mechanical loading, such as basketball and soccer, are associated with higher BMD, whereas non-weight-bearing sports like swimming show lower BMD levels [2]. LEA disrupts testosterone regulation in males, impairing bone remodeling and increasing injury risk [3-5].

Sleep is essential for recovery, cognitive function, and injury prevention, but athletes often experience sleep disturbances due to training and competition stress. Poor sleep exacerbates LEA's effects, reducing reaction time, neuromuscular coordination, and overall performance [6]. Vertical jump performance, an indicator of explosive power, is influenced by BMD and energy status. Athletes with higher BMD better withstand repeated impact, while those with LEA and poor sleep show reduced jump height [7].

The selection of these parameters is rooted in their significant impact on an athlete's overall health, performance, and recovery. LEA can disrupt physiological processes, leading to impaired BMD, poor sleep quality, and reduced neuromuscular function. Compromised BMD increases the risk of stress fractures [8], while inadequate sleep hinders muscle recovery, cognitive function, and overall athletic performance [9]. Neuromuscular function, essential for power and agility, is directly influenced by energy intake and recovery quality [10]. By examining the relationship between these factors, this study aims to bridge existing knowledge gaps in male athletes. Early identification of these issues can lead to targeted interventions in sports nutrition and recovery strategies, reducing injury risk and enhancing performance longevity. This research contributes to developing evidence-based approaches to optimize training regimens, ensuring athletes maintain peak physical condition while safeguarding long-term health and performance sustainability.

Material and Methods

Design

This cross-sectional observational study was conducted at Guru Nanak Dev University. The study aimed to examine the relationships between LEA, BMD, and Sleep Quality with vertical jump performance in male team sports athletes.

Participants

A total of 64 male athletes, aged between 18-24 years participated in the study. The study was approved by the institutional ethical committee of Guru Nanak Dev University approval number no.- 2719/HG Dated- 13-05-24). Athletes were recruited from various team sports, including football, basketball, handball, cricket, volleyball, and were free from any recent injury 6months or musculoskeletal pain and any type of neurological/ cognitive impairment and injuries which can affect the outcome of the study. Written informed consent was obtained from participants. Mean height and weight were recorded as mentioned in the table 1.

Procedure

Demographic data such as name, age, gender, height, weight was documented with the consent forms for the procedure.

Bone Mineral Density (DEXA Scan) [8]

For assessing BMD, the DEXA scan Hologic discovery ™ QDR was utilized, renowned for its precision in measuring bone strength. Participants were required to remove metallic items, like jewellery, belts, or accessories, as these could cause interference in imaging. Each participant was placed supine on the DEXA scanner bed to ensure proper positioning for consistency. The scan was focused on the lumbar spine and hips, areas susceptible to energy deficiency-related changes. The procedure lasted about 10–15 minutes per participant, with a low exposure to radiation, in line with safety protocols. All scans were conducted by qualified technicians to ensure accuracy and participant comfort.

Low Energy Availability-Questionnaire (LEAM-Q) [1]

The LEAM-Q was completed privately, assessing dietary intake, training load, and LEA symptoms. Sessions lasted 20–30 minutes, with researchers clarifying terms for accuracy. Responses were confidentially recorded for reliable analysis.

Pittsburgh Sleep Quality Index (PSQI) [9]

Sleep quality was evaluated using the PSQI, covering seven components, including sleep latency, duration, and efficiency. Higher scores indicated poorer sleep quality, offering insight into recovery and performance.

Vertical Jump Height Test [7]

Vertical jump capability was measured by a standardized test of jump height. Participants received a controlled warm-up to prevent injury. The testing area contained a calibrated vertical jump measurement device. Athletes were shoulder-width apart and executed maximal vertical jumps with arm swing for propulsion. Each participant was allowed three attempts, with adequate rest between trials to prevent fatigue. The optimal jump was analyzed, proper technique was reinforced, with real-time feedback to promote consistency and accuracy.

Statistical Analysis

Statistical analysis was done using IBM SPSS Statistics software 27.0 with a significance level of $p < 0.05$. Kolmogorov-Smirnov test was used to determine data normality. Spearman correlation was used for BMD and vertical jump height, whereas Pearson correlation was used for PSQI and LEAM-Q. Descriptive statistics of mean and standard deviation were used to summarize participant characteristics. Sample size was calculated using G-Power software. These analyses helped to determine the relationship between energy availability, bone health, sleep quality, and athletic performance and to determine their combined effect on vertical jump performance.

Results

Table 1: Demographic data of the included participants.

Demographics Variables	**Mean ± SD**
Age (years)	22.22 ± 1.68
Height (cm)	175.05 ± 7.53
Weight (kg)	69.45 ± 10.12
BMD Z Score	0.08 ± 0.97
PSQI Score	4.52 ± 2.61
LEAM-Q Score	17.94 ± 6.96
Jump Height (cm)	35.12 ± 9.49
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Abbreviation: cm: centimeter, kg: kilogram

The table 1 depicts the mean and standard deviation of age, height, weight and BMD score, PSQI score, LEAM-Q score and Jump Height of the participants.

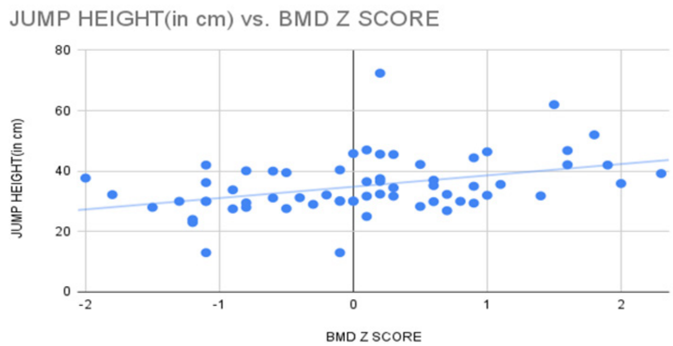

Figure 1: Correlation between vertical jump height and BMD.

The graph 1 shows the correlation between BMD (on x-axis) and Jump Height (on y-axis) which is having the p = 0.002 and r = 0.358 showing a moderate positive correlation.

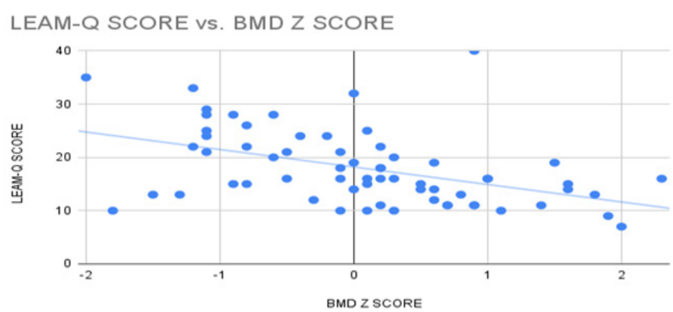

Figure 2: Correlation between BMD and LEAM –Q.

The graph shows the correlation between Low Energy Availability (on x-axis) and Bone Mineral Density (on y-axis) showing P < 0.001* and r = -0.455 showing a significant negative correlation.

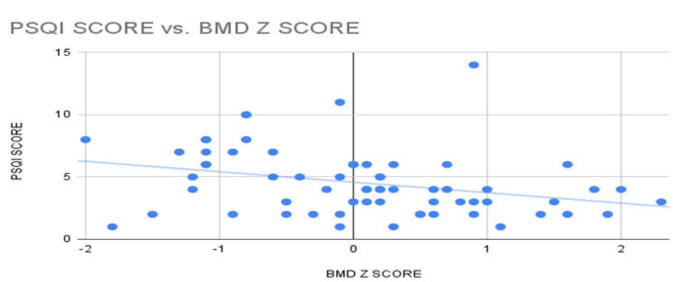

Figure 3: Correlation between PSQI and BMD.

The graph shows the correlation between BMD (on x-axis) and PSQI (on y-axis) showing p = 0.012 and r = -0.311 showing a moderate negative correlation indicating that athletes with poorer sleep quality exhibited lower bone mineral density.

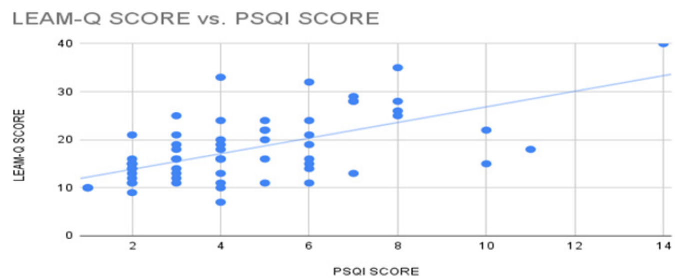

Figure 4: Correlation between LEAM-Q and PSQI.

The graph shows significant correlation between PSQI (on x-axis) and LEAM-Q (on y-axis) showing p < 0.001 and r = 0.609, suggesting that athletes with lower energy availability also experienced poorer sleep.

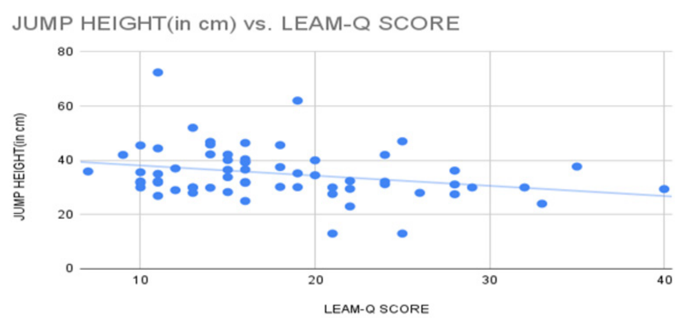

Figure 5: Correlation between vertical jump height and LEAM-Q.

The graph shows weak correlation between LEAM-Q (on x-axis) and vertical jump height (on y-axis) showing p = 0.027 and r = -0.277, indicating that athletes with lower energy availability performed worse in vertical jump tests.

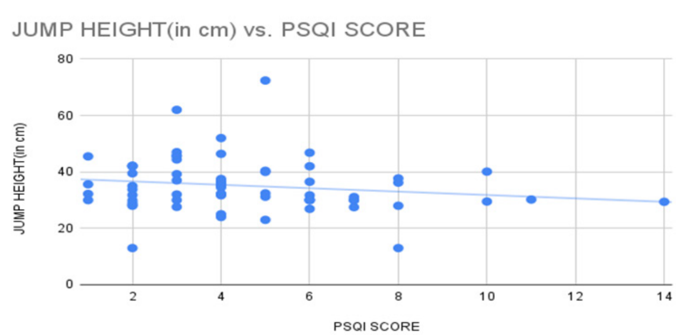

Figure 6: Correlation between vertical jump height and PSQI.

The graph shows weak correlation between PSQI (on x-axis) and vertical jump height (on y-axis) showing p = 0.187 and r = -0.167, which was not statistically significant.

Figure 7: DEXA scan machine.

This figure shows a player is performing DEXA scan measuring its body composition bone mineral density.

Figure 8: Jump Height.

The figure illustrates the initial position of vertical jump height measurement test for explosive power of an athlete for calculating its vertical jump height.

Discussion

This study highlights the intricate relationship between energy availability, BMD, sleep quality, and vertical jump performance in male team sport athletes. The findings suggest a positive correlation between BMD and jump height, reinforcing the idea that skeletal health plays a crucial role in explosive movements [11,12]. Additionally, LEA was negatively associated with BMD and vertical jump performance, supporting prior research linking insufficient caloric intake to impaired musculoskeletal function and reduced athletic capacity [7,13]. These results are particularly significant for male athletes, who may not exhibit the overt physiological symptoms often observed in female athletes with LEA, making early detection and intervention more challenging [3]. Given these findings, regular nutritional assessments in athletes are essential to prevent energy deficits that could lead to reduced power output and increased injury susceptibility.

Furthermore, poor sleep quality showed a strong association with LEA and lower BMD, suggesting that sleep disturbances could indirectly influence performance by exacerbating energy deficits and impairing recovery [9]. While sleep quality itself did not show a direct correlation with jump height, its impact on neuromuscular function, metabolic processes, and injury risk suggests an indirect influence that warrants further investigation [14]. Chronic sleep deprivation is associated with elevated cortisol levels, reduced growth hormone secretion, and impaired neuromuscular function, which could progressively hinder athletic performance [10]. These findings indicate that monitoring sleep hygiene should be a crucial part of athlete recovery protocols. Given the critical role of sleep during hormonal regulation, cognitive function, and physiological recovery, even subtle impairments in sleep quality may contribute to long-term performance decrements.

The observed positive correlation between BMD and vertical jump height aligns with prior research demonstrating that higher bone density enhances an athlete's ability to withstand mechanical loading and optimize force transmission [15]. Bone serves as a rigid framework that supports muscular contractions, neuromuscular efficiency, and force production, which are essential for power-based movements. Additionally, higher BMD reduces the risk of stress fractures, a common issue in athletes experiencing insufficient bone remodeling due to energy deficits [8]. Athletes engaged in repetitive high-impact activities such as sprinting, jumping, and abrupt directional changes place significant mechanical stress on their skeletal structures, which, if unsupported by sufficient BMD, can increase injury susceptibility and performance decrements. Strength training and bone-loading exercises are essential for maintaining skeletal integrity, as resistance training and plyometric exercises have been shown to enhance BMD by promoting osteogenic loading [6]. However, chronic LEA can suppress bone turnover, leading to osteopenia and osteoporosis, thereby compromising performance and increasing injury risk [13].

The negative correlation between LEA and vertical jump height suggests that insufficient energy intake impairs muscle function, neuromuscular efficiency, and anaerobic capacity, all of which are critical for explosive movements. LEA has been linked to hormonal imbalances, glycogen depletion, and decreased muscle protein synthesis, leading to compromised power output and endurance [17]. Additionally, LEA can induce metabolic adaptations that prioritize vital physiological functions, such as organ maintenance, while downregulating muscle repair and recovery, ultimately impairing athletic performance. Implementing structured energy availability assessments in male team sports athletes could play a crucial role in the early identification and prevention of performance decline and long-term health risks. While sleep quality did not significantly correlate with vertical jump height, its role in recovery, cognitive function, and overall athletic readiness should not be overlooked [9]. Sleep is crucial for hormonal regulation, including the secretion of growth hormone and testosterone, which influence muscle repair and neuromuscular performance. Poor sleep has been associated with elevated cortisol levels, reduced glycogen resynthesis, and impaired immune function, all of which can hinder performance. Moreover, chronic sleep deprivation has been shown to impair reaction time, decision-making, and coordination, which are vital for athletic success [10]. Although this study did not find a strong link between sleep and jump height, future research should explore how sleep interventions, such as improving sleep hygiene and napping strategies, influence neuromuscular performance in athletes.

The results of this study emphasize the interdependence of energy availability, bone density, and sleep quality in athletic performance. To optimize jump performance and overall athletic output, sports practitioners should adopt a comprehensive and integrative approach that considers multiple physiological factors. Ensuring adequate energy intake is crucial, as addressing LEA through personalized nutrition strategies can help support bone health, muscle function, and recovery [13]. A well-structured strength and conditioning program is also essential, incorporating weight-bearing exercises and plyometric training to enhance BMD and neuromuscular efficiency [8]. Additionally, prioritizing sleep hygiene and recovery strategies should be emphasized, as proper sleep is fundamental for hormonal balance, muscle repair, and athletic readiness. Monitoring athletes for RED-S and overtraining syndrome is equally important, as regular screening can help identify signs of low energy availability, poor recovery, and declining performance before they lead to serious health consequences. Future research should focus on the long-term effects of LEA on bone health and neuromuscular adaptations, particularly in power-based sports, and explore the efficacy of sleep interventions in optimizing recovery and athletic performance.

Conclusion

In conclusion, this study emphasizes the key functions of LEA and BMD in vertical jump performance in male team sports players. More favourable BMD was positively correlated with increased jump height, putting high emphasis on skeletal system quality in improving explosive power. Conversely, LEA was negatively correlated with jump performance, where low energy availability leads to impaired sports ability through impact on muscle performance, recovery, and bone mineralization.

Despite poor negative correlation, sleep quality is still a key variable for overall recovery and performance. These findings lend support to the need for a multidimensional approach to the management of athletes, where energy intake, bone mineral quality, and recovery through sleep are all optimized to improve performance and reduce risk of injury. By treating all these inter-linked factors, players are able to optimize their potential and remain successful in team sports for longer.

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