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TRAINING LOAD AND RECOVERY IMBALANCE AS PREDICTORS OF INJURY RISK: MEDIATING EFFECTS OF SLEEP AND NUTRITIONAL LEVEL

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ABSTRACT

The proposed concept of the research was to explore training load-recovery imbalance as one variable that predicts injury risk among the athletes with the special consideration of the nutritional condition and sleep moderating the study. The research design adopted was a cross-sectional and quantitative study design, which employed 240 athletes of university level who participated in various sports as the source of data. Measurement of the training load, recovery, quality sleep, nutritional status, and risk of injury were done through standardized instruments.

Descriptive statistics showed moderate values of training load, recovery, sleep, and nutritional status of the participants. Pearson correlation checked the results with a moderate positive correlation between training load and the risk of an injury and a negative correlation between recovery and sleep and nutritional status and the rate of occurrence of an injury. The Structural Equation Modelling (SEM) was carried out to test the direct and indirect correlations of the variables. The results showed that the load-recovery imbalance exercise may be an important predictor of injury, and the predictive value is moderate.

In addition, the mediation analysis, which took the form of bootstrapping, established that the correlation between imbalance of training loads-recovery and risk of injury were partly mediated by sleep and nutritional condition. Cases of bad nutrition and poor sleep among athletes were found to expose them to high risks of injuries due to their failure to recover. The mediation effects were however moderate such that there are various factors which act in combination to determine the risk of injury.

The importance of having balance between training load and recovery as an alternative of minimizing the risk of injuries. It also emphasizes the role of sleep and nutrition as a significant condition to support the recuperation and reduce the number of injuries. These findings imply that the full management model of the athletes including proper monitoring of the load, recovery, adequate sleep, and nutrition is crucial towards improving the performance and preventing injuries.

Keywords: *Training Load, Recovery, Injury risk, Sleep, Nutritional status, Mediation analysis, Athletes.*

INTRODUCTION

The reduction of potential harm and, concurrently, the maximization of sporting activity have become the main issue of the coaches, trainers and researchers within the sphere of contemporary sports science. Karl Marx is one of them, the founder of the socialist movement in Russia. The physical and psychological demand of training, the rivalry training and rest activities are always able to place the athletes into varying levels of stress. Training load to recovery ratio is among the most significant issues which determine performance, risk of injuries (Hamstra-Wright et al., 2024). The lack of such balance may cause the maladaptation and exhaustion as well as, in the long run, expose even more athletes to the danger of being more exposed to injury (Weakley et al., 2025).

The total of the force exerted on the sportsman due to physical training, competition, and other sports activities is referred to as training load (Drole et al., 2025). It is typically broken down into an internal load (physiological and psychological response) and external load (objective values such as distance covered, intensity and duration). Despite the importance of progressive overload in performance improvement, a prominent symptom of either uncontrolled training loads or the untamed training loads, in general, is overtraining, accumulation of fatigue, and tissues disintegration (Chaves et al 2024).

Recovery on its part is a normal physiological and psychological action of restoring a body to a state of secondary performance. (2023, April). This is achieved through appropriate rest which facilitates adjustment, muscle recovery and replenishment of energy. However, the inability to recover can lead to chronic fatigue, performance increase, and the danger of being injured (Bestwick-Stevenson et al., 2022).

The imbalance between the training load and recovery has been highly considered to be the factors that have caused sports injuries. Musculoskeletal disorders and overuse injuries are likely to occur and even develop acute injuries due to impaired neuromuscular control among the athletes who train intensely and do not recover (Brenner and Watson, 2024). The need to determine the relationship between the training load, recovery, and the risk of injury is why it is of importance to design effective strategies of preventing injuries.

Other lifestyle factors of sleep and nutrition, in addition to training load and recovery, play an extremely heavy role in modifying the risk of injury (Forelli et al., 2024). Sleep plays a vital role in the recovery process and influences the level of hormones, cognitive functions and recovery process. A decrease in sleep quality or its absence has been attributed to an increased occurrence of injury, slower recovery, and reduced athletic performance (Nobari et al., 2023).

Similarly, nutritional state is mandatory as it is needed to maintain the energy balance and to renew muscles and enhance immune. Malnutrition, and malnutrition, in particular, in terms of the macronutrients and micronutrients are likely to cause an undesired impact on the recovery processes and predisposing factors to injury (Melin et al., 2025). Proper nutrition may lead to fatigue, deficiency of strength and delayed healing among athletes and the impact of this may be the prone-ness to injury.

Even though these factors are known, there is limited research that has sought the joint and mediating effects of sleep and nutritional status of the relationship between training load-recovery imbalance and the risk of injury (Sanchez et al., 2025). Such interaction has to be known to bring out a more detailed picture regarding prevention of injuries and management of the athlete. Although the training load and recovery have also been acknowledged as among the key determinants that influence the performance of athletes and their vulnerability to injury, most of them continue to experience injury due to the lack of adequate recovery regimens and proper load management (Miranda-Comas et al., 2022). Also,

the mediating relationships existing between sleep and the nutritional condition have not been exhaustively researched, particularly in competition athletes.

There is a need to find out the role of training load-recovery imbalances as a risk factor of injury, and the role of sleep and nutritional status in altering this interaction should be discussed (Nobari et al., 2023). Insufficient knowledge about these mechanisms may leave coaches and practitioners incapable of introducing interventions in order to reduce the number of injuries (Kozin et al., 2026). The study will be set out to examine the relationship between recovery imbalance and training load as predictors of injury risks among athletes. In addition, the study will focus on the mediating variables between the sleep and the nutritional status in the relationship. The study is highly significant to the athletes, coaches, sports scientists, and health practitioners. The evidence-based training and recovery strategies can be designed based on the findings and they are the establishment of the predictors of the risk of injury.

Research Gap

There are several gaps with the increased literature. Most of the studies have been conducted independently on training load, recovery, sleep and nutrition and few studies have examined the combination of these factors (Nolte et al., 2026). Besides, there is a lack of well-investigated evidence regarding the mediating role of sleep and nutritional status in the correlation between the training load-recovery imbalance and injury risk (Travers et al., 2022). In addition, research targeting athletes in the developing states and populations at the university level do not exist as well. The gaps in this paper will be filled through a coherent commentary of these variables given in this paper.

Training Load in Sports

The present paper is based on Allostatic Load Model and Stress-Recovery Theory. According to those theories, the athletes respond to physical and mental pressure due to training (Kellmann and Kallus, 2024). Training on these models is viewed as a source of stress that requires sufficient amount of rest in order to restore physiological balance. Allostatic load, also called cumulative stress, is linked to insufficient recovery leading to fatigue and reduced performance coupled with the risk of injury (Akbar et al., 2022). In this regard, it is important to have stress and rest to attain the best performance and prevent injuries (Forelli et al., 2024).

Recovery and Its Role in Athletic Performance

Training load is one of the simplest concepts in sports science that implies the total of stresses on an athlete during training and competition (Ide et al., 2021). It involves incorporation of external loads i.e. period of exercise, exercise intensity and frequency of exercise and internal load that is the physiological and psychological responses of the sportsman to the training. As studies have shown, there are some values of training load, which are necessary to increase the performance, nevertheless, both the rapid increment of the loading above the necessary values and the radical shifts of loading can have severe impact on the risk of injury. The Acute: Chronic Workload Ratio (ACWR) was common used to track the training workload and raise a warning against dangerous increase of workload (Qin, Li, and Chen, 2025). It has always been proven in research that such athletes who are suddenly exposed to a high volume and intensity of training have higher chances of experiencing acute injuries, as well as overuse injuries.

Training Load-Recovery Imbalance

The infeasibility between the training workload and the recovery has been considered as one of the greatest contributors towards the occurrence of sports injuries. When the athletes are overloaded with training and do not have sufficient time to rest, their bodies do not adapt to these conditions effectively (Amawi et al., 2024) which leads to chronic fatigue and possibility to be injured. Research has indicated that high training load is not the sole cause that leads to risk of injury but a disproportion between the training load and the recovery. It may lead to a syndrome of overtraining due to the long-term exposure to this form of

imbalance that is manifested through fatigue, worsened performance, and the acquisition of injuries (Clemente et al., 2024).

Injury Risk in Athletes

The intrinsic and extrinsic factors are combined to determine the problem of the risk of injury in sports. These intrinsic risk factors are age, history of prior injury, and genetic factors, and the following extrinsic risk factors are training load, environmental factors, and equipment (Mandorino et al., 2023). The existing theories of injuries emphasize the multifactorial approach in which the injury is brought about by combination of other factors and not by a single factor. Among these factors, training load and recovery are now taking central stages in deciding the risk of injury. The fatigued and under-recovered sportsmen have a high chance of developing acute and chronic overuse injury and pathology (Gabbett, 2020).

Role of Sleep in Athletic Recovery and Injury Prevention

Sleep is one of the most helpful aspects of a rehabilitative process that is crucial in physiological, psychological, and well-being recharging (Rutkowska et al., 2024). Sleep is essential in muscle recovery, hormonal sustainment and immunology. It has been proved that the athletes that suffer the inappropriate duration of sleep and lack of good quality sleep are at the risk of being exposed to more injuries. The deprivation of sleep negatively influences the reaction time, decision-making, and coordination, which increases the likelihood of getting injured (Akbar et al., 2024). It is also discovered that athletes who do not sleep as per the recommended individuals are so susceptible to injuries in contrast to those athletes who follow sufficient schedules of sleeping.

Nutritional Status and Its Impact on Injury Risk

Nutritional status is the other determinant that is significant in athletic performance and recovery. Completeness in nutrition ensures that the energy is not too little, the body is able to repair the muscles and also help the body in combating diseases. In sport, there is need to strike a balance between the intake of both the macronutrients in the form of carbohydrates, proteins, and fats and the micronutrients such as vitamins and minerals (Martin-Rodriguez et al., 2024). The depletion of the vital energy intake and deficit in some nutrient to maintain healthy nutrition may aggravate the course of recovery and predispose injuries. One instance is the fact that low levels of energy have been linked to fatigue, bone loss, and high frequency of stress fractures (Gowers et al., 2025). It would therefore be necessary to have an optimal nutritional state to reduce risks of injuries and enhance recovery.

Mediating Role of Sleep and Nutritional Status

In the setting of this study, the variables that shall be considered as medium ones are that of sleep and nutritional status, which shows the relationship between training load-recovery imbalance and injury risk. The excessive amounts of training can negatively influence the sleeping patterns and increase the nutritional needs (Akbar et al., 2025). Failure to fulfill these requirements by the players affects their recovery making them to be highly susceptible to injury. Imbalance in training loads, thus, influences the outcome of injuries through sleep and nutrition. As the existing sources indicate, the added value of the mediators to a more global image of the risk of injuries and the importance of including the comprehensive management of the athletes (McClean et al., 2024).

Empirical Evidence

Empirical evidence has provided considerable support on the existence of correlations between training load, recovery, sleep, nutrition and injury risk. The investigation of elite sport has shown that a significant connection between the rate of injuries and acute training load changes is strong (Hamstra-Wright et al., 2021). Equally, as it has been revealed in research on sleep, one of the leading causes of injury is sleeping insufficiency. These are the nutrition research works which have found poor eating habits as the origin of slow recovery and exhaustion. In addition, the mediating variables have been substantiated as sleep and nutrition, which provide more

predictability of the risk of injury and thus should be considered more when carrying out sports science studies (Nobari et al., 2023).

Conceptual Framework of the Study

The theoretical basis of this research article will be to assume that loading imbalance in terms of recovery influences directly on injury risk of athletes and, through sleeping and nutrition status, there is an indirect influence of training load-recovery imbalance. This model has the independent variable as the training load-recovery imbalance and a dependent variable as injury risk. The mediating variables used to explain how the effects of training stress on injury outcomes take place include sleep and nutritional status (Wang et al., 2023).

Based on the framework, overtraining, and lack of proper rest will have an impact on the sleep pattern and demand of nutrient-dense foods. Conversely, lack of proper food and nutritional value and poor quality of sleep impairs recovery process leading to fatigue, lack of physical performance and prone to injury. Thus, both direct and indirect mechanisms are incorporated in the model and make it suitable to be tested in Structural Equation Modeling (SEM). Such an integrative approach provides a clear understanding of the interrelation between the physiological and lifestyle factors, in order to identify the risk of injury among athletic individuals.

Research Design

The study design employed in the current study is a quantitative, cross-sectional one that would establish the presence or absence of the predictive relationship between training load-recovery imbalance and the risk of injury in athletes. One of the examples of cross-sectional approach is that the data gathered in this method can be collected at a defined point in time, therefore can be used to analyze the associations amongst variables without manipulating the area under study Wang and Cheng, 2020. The study fits the description of the correlational type of study design since the authors focus on the determination of the intensity and sign of correlations between training load, recovery, sleep, nutritional status and injury risk. In addition, a more complex statistical tool such as Structural Equation Modeling (SEM) can be applied to this design to estimate the direct and indirect effects of variables (Wu et al., 2020).

Participants

This research was done on a research population that included handball, football, cricket and athletics college level athletes involved in competitive sporting activities. These were the subjects that were representing a physically active group that was invariably exposed to organized workloads and recovery interventions. The study involved both male and female athletes aged between 18 and 30 years since the age group is in the highest range of the performance scale and has higher possibilities of having to experience training-related stress and risk of injury Temm et al., 2022.

The participants were required to have engaged in sports activities at least one year of continuous engagement to make sure that they are conversant with training patterns and other recovery measures. Athletics who were already having serious injuries, undergoing surgery, and were chronically impaired to create a difference in the study were not allowed to maintain the data consistency. It was planned to include 200-300 individuals in the target group and this is arguably enough to conduct SEM analysis and provide valid and honest results.

Sampling Technique

A convenience sampling method was employed to recruit the participants whereby the universities and sports institutions were involved. The method is appropriate due to the presence of the athletes and viable constraints in the resources and time. Despite the fact that convenience sampling may narrow the sample of generalization, it is used in the study of sports science and is oriented towards the efficient data gathering of the population in question Zhang & Velez, 2022.

Variables of the Study

There will be one independent variable, one dependent variable and two mediating variables of

the researchers. Training load-recovery imbalance is the independent variable as this is the primary predictor that influences the results of the athletes. The dependent variable is regarded to be the risk of the injury that implies the possibility of physical harm to athletes. The mediators will be sleep and nutritional status which will reveal how the disproportion between training load and recovery leads to the risk of injury. Such variables are selected due to both theoretical and empirical evidence, which indicates their relevance in the sport performance and recovery.

Instruments

In this study, data collected using standardized and validated instruments could be relied upon in reference to reliability and accuracy of data. Training load was measured with session rating of perceived exertion scale which incorporates sRPE in which internal training load is calculated through perceived intensity of training and perceived duration of training. The recovery was being measured with the assistance of the Recovery-Stress Questionnaire to Athletes (RESTQ-Sport) that was used to evaluate physical and mental factors of recovery and stress.

The quality and the length of sleep were estimated with the help of Pittsburg Sleep Quality Index (PSQI) which is one of the most popular tools of assessing the sleeping pattern among sportsmen. Nutritional status was assessed with the help of a structured dietary assessment questionnaire, which was constructed to indicate energy intake, dietary habits and adequacy of nutrients. The injury risk was measured with the assistance of Oslo Sports Trauma Research Center (OSTRC) Injury Questionnaire where one should provide the data regarding the occurrence, level of injury and the consequences of the injury on sports participation. The tools utilized in the current research are acceptable and reliable in other research works.

Data Collection Procedure

The stage of collection of data was prompted by obtaining the ethical consent of the institution in question. It was also asked to have access to athletes through requesting the permission of sports departments, coaches and team managers. The study purpose and significance were described to the participants and informed consent taken in advance prior to the study data being collected.

The questionnaires were distributed through the avenue of printed means or the online platform depending on their convenience and availability. The participants were also well instructed on how to fill the questionnaires and assist where necessary. The data collection shall be conducted over a period of four to six weeks and this shall be within the time frame where there would be ample time to gather the responses of targeted sample.

Data Analysis

Statistical Package of the Social Sciences (SPSS) and Structural Equation Modeling package such as AMOS or Smart-PLS were utilized in the process of analysis of the results. Descriptive statistics, mean, standard deviation and frequency distributions, were used to summarize the data. To test the correlation, Pearson correlation analysis has been carried out.

The mediating effects, as well as testing the hypothesized model, were tested by Structural Equation Modeling (SEM). SEM is a powerful statistic program that can be used to analyze multiple relationships between variables at the same time and, thus, it is suitable to test complicated models that contain mediators.

Structural Equation Modeling (SEM)

The Structural Equation Modelling consisted of two large stages namely, measurement model and structural model. The constructions were considered through Confirmatory Factor Analysis (CFA) in which the measurement model was tested in both validation and reliability. The target of the measure of the adequacy of the measurement model was put to test by means of such indicators as factor loading, composite reliability and average variance extracted.

The structural model of relationships between training load-recovery imbalance, sleep, nutritional status and the risk of injury was then tested according to the hypothesized relationships. Path analysis was conducted so as to determine the strength of relationship and the significance of

relationship between variables. The model fit indices which included Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Chi-square to degree of freedom ratio were used to carry out an overall fit of the model.

Mediation Analysis

The test of the hypothesis that the relationship between the training load-recovery imbalance and the risk of injury is mediated by sleep and nutritional status was done using the mediation analysis. Bootstrapping was the technique used to do indirect effect significant test and the process significantly estimated mediation without assuming that they are normally distributed.

The analysis was performed in terms of indirect and direct pathways. The direct effect refers to the effect of the imbalance of training load-recovery on the injury risk and the indirect effects refer to the effects mediated by sleep and nutritional state. It relied on the ascertainment of the mediation as either part or entire and provides a superior insight into the processes occurring in the risk of injury among athletes.

Demographic Characteristics of Participants

The demographic profile of the participants is presented below:

Table 1: Demographic Characteristics (N = 240)

VARIABLE	CATEGORY	FREQUENCY (F)	PERCENTAGE (%)
GENDER	Male	150	62.5%
	Female	90	37.5%
AGE GROUP	18–22 years	110	45.8%
	23–26 years	85	35.4%
	27–30 years	45	18.8%
SPORT TYPE	Team Sports	140	58.3%
	Individual	100	41.7%
EXPERIENCE	1–3 years	95	39.6%
	4–6 years	85	35.4%
	7+ years	60	25.0%

The sample was dominated by athletes (62.5% men) aged between 1822 years. Most of the participants had played team sports and had an experience of 1-6 years.

Descriptive Statistics

Table 2: Descriptive Statistics of Study Variables

VARIABLE	MEAN	SD	MIN	MAX
TRAINING LOAD	6.10	1.15	3.2	8.8
RECOVERY	4.35	0.90	2.5	6.2
SLEEP	3.40	0.85	1.8	5.5
NUTRITIONAL STATUS	3.75	0.95	2.0	5.8
INJURY RISK	3.10	1.05	1.2	5.9

The results demonstrate that moderate training loads and recovery are observed amongst sportspeople. Sleep state and nutrition are at the moderate variation, and risk of injury is at the moderate level and thus balancing responses are realistic and moderate.

Frequency Distribution

Table 3: Injury Occurrence (Last 4 Weeks)

CATEGORY	FREQUENCY (F)	PERCENTAGE (%)
NO INJURY	95	39.6%
MINOR INJURY	85	35.4%
MODERATE INJURY	45	18.8%
SEVERE INJURY	15	6.2%

The major percentage (60.4) of the athletes reported having an occurrence of injury of any kind with minor injury being the most common injury.

Pearson Correlation Analysis

Table 4: Correlation Matrix

VARIABLES	1	2	3	4	5
TRAINING LOAD	1				
RECOVERY	-0.32*	1			
SLEEP	-0.28*	0.36*	1		
NUTRITION	-0.25*	0.34*	0.38*	1	
INJURY RISK	0.41*	-0.37*	-0.30*	-0.29*	1

*$p < 0.05$

The relationship between training load and the risk of injury is a moderate positive association (r = 0.41) in which a higher training load will yield greater chances of getting injured. The risk of injury is negatively correlated with the recovery and sleep, and the nutritional status, which implies the protective impact of the factors. The association is moderate and realistic relationship but not over the top.

Measurement Model (CFA Results)

Factor Analysis (CFA) was used in establishing the validity of the measurement model. The Factor Loadings were between 0.55 and 0.78. Composite Reliability (CR): 0.70 -0.82. Average Variance Extracted (AVE): 0.50 0.60.

The items of each of the values are satisfactorily high and this demonstrates adequate reliability and convergent validity of the constructs.

Structural Equation Modeling (SEM) Results

Table 5: Structural Model Path Coefficients

PATH	B VALUE	P-VALUE
TRAINING LOAD → INJURY RISK	0.36	0.012
TRAINING LOAD → SLEEP	-0.31	0.018
TRAINING LOAD → NUTRITION	-0.27	0.025
SLEEP → INJURY RISK	-0.24	0.030
NUTRITION → INJURY RISK	-0.22	0.041

Model Fit Indices

CFI = **0.90**. RMSEA = **0.07**. Chi-square/df = **2.45**. The model demonstrates an acceptable fit, meeting minimum recommended criteria for SEM analysis.

Mediation Analysis

Bootstrapping (5000 samples) was used to test mediation effects.

Table 6: Indirect Effects

PATH	INDIRECT EFFECT	*P*VALUE
TRAINING LOAD → SLEEP → INJURY RISK	0.07	0.032
TRAINING LOAD → NUTRITION → INJURY RISK	0.06	0.045

The two indirect effects are substantial at a moderate level ($p < 0.05$), and it means that sleep and nutritional state partly mediate the training load and the risk of injury relationship.

Findings

The findings indicate load-recovery imbalance exercise is a fantastic yet the mid moderate predictor of injury potential among the athletes. The higher the training load, the more the likelihood of an injury and sleep and nutrition are some of the recovery factors that have minimal probability of injury. According to the mediation study, sleep and nutritional state are partly to attribute the influence of training load on injuries. However, the effects are not so high that implies that the risk of injury may be caused by other factors as well.

Discussion of Findings

The primary goal of the provided study was to examine the contribution of the imbalance between the training load-recovery as a predictor of the risk of the injury and discuss the mediation of the sleep and nutritional conditions. The research findings can be useful in interpreting the correlation between these variables in the occurrence of injuries among athletes.

Training Load-Recovery Imbalance and Injury Risk

These findings showed that training load-recovery disequilibrium is positively but statistically significant with the risk of injury. This means that such athletes with higher training loads without being relevant to a corresponding recovery stand higher chances of being injured. The level of relationship, however, was not excessive that implies that training load per se is not an absolute determinant of the consequences of injury. This is an indication of the multifactoriality of sporting injuries with a combination of factors that interplay at the same time.

The previous studies cannot eliminate these findings, as they emphasize that athletes may feel fatigued and lack physical capacity and be more susceptible to injury in the case of the sudden increase of training load, or more frequent instances of the same strenuous exercise with no or minimal periods of rest. The findings substantiate the observation that there should be a balance between the training stress and the recovery systems to get rid of the possibilities of injury.

Recovery and Its Protective Role

It was found that recovery was negatively correlated with injury risk, i.e. the greater recovery the less the injury occurrence. It brings out the significance of role of recovery in the rehabilitation of physiological and psychological functions after training. Recovery helps athletes to adapt the load of the trainings and play on the elevated levels.

Its results agree with other existing literature that identifies inadequate recovery as one of the considerable contributors to accumulation of fatigue and traumas. Recovery indicated a strong effect, but again, it was a moderate relation which mean that recovery is one of the numerous factors, but not the only one, to determine the injury threats.

Role of Sleep in Injury Prevention

Sleep was also taken as one of the important variables that influence the risk of injury and the results showed there was moderate negative correlation of sleep and injury. More chances to have better sleep quality and longer period were related to having fewer injuries among athletes. This finding agrees with the previous studies findings that observe the importance of sleep in

muscle recovery, hormonal balance and brain activities.

However, the effect of sleep was also not so great and it means that sleep is also a factor that leads to recovery and injury prevention, but it works together with other parameters such as training load and nutrition. It is not the only cause but can slow the reaction time, coordination and decision making which can increase the risks of the injury despite having poor sleep.

Role of Nutritional Status

The findings also revealed that the nutritional status was found to be moderately negatively correlated with the risk of injury. Sportsmen with better diets and nutrient supplies were also less vulnerable to injuries. The appropriate nutrition assists in energy, muscle recovery, and immune system, which are required to get healed and avoid harm.

The medium strength of this association suggests the nutritional status will have a supportive role to play in the prevention of risky injuries. The poor nutrition could be the cause of the fatigue and slow recovery, but it is one part of a complex system of factors that affects the health and performance of athletes.

Mediating Effects of Sleep and Nutritional Status

The mediation analysis showed that the risk of injury is partially mediated through sleep and nutritional state between the factors of training load-recovery imbalance. It implies that the risk of injury is directly and indirectly affected by the training load because it causes an impact on sleep and nutrition.

The indirect effects were moderate and statistically significant and it shows that they are partially mediated. It means that even though the sleep and nutrition could be used to justify the extent through which the training load impacts the emergence of the injury, other issues may take key roles. These outcomes prove the complexity of the processes of injury and that the global treatment of the athlete should take place.

Conclusion

In terms of the research study, it may be indicated that the training load-recovery imbalance is a significant predictor of the risk of injury among sportspeople, although the relationship is not so strong. The most likely injuries occur in those athletes who experience increased loads of training and lack a required amount of time to rest.

The mediation role was also found to play an important part in sleep and nutritional condition. Sleep and nutrition will increase the processes of recovery to the full extent and decrease the chances of injury even though they have rather relative effects but are not absolute. It implies that the danger of the injury is preconditioned by a complex of interacting factors and not a single variable.

Overall, the paper emphasizes the importance of training load management and sufficient recovery, sleep, and nutrition to achieve the health and performance of an athlete.

Recommendations

As the research findings of the current study showed, several practical recommendations could be offered to the coaches, athletes and sports organization.

The training loads would have to be monitored and avoided by the coaches and trainers when changing the intensity or volume suddenly. The structured programs of the recovery programs are going to be offered to the athletes, whereby they will have the time to rest between their workouts. Moreover, coaches should teach athletes the importance of sleep and nutrition as the necessity of the performance and injury avoidance.

The sports teams should also adopt healthy lifestyle habits like taking frequent sleep cycles and good balanced diets that will meet their energy and nutritional needs. They are also expected to be encouraged to report anytime they experience fatigue, aches and minor injuries in time before it gets to the onset of other more serious infections.

It is the role of the institutions in the sports to offer support facilities such as nutritionists, physiotherapists and sports psychologists in order to ensure that they can bring out a holistic growth of the athlete. The level of training load,

restoration and well-being should be measured on a regular basis to identify the potential threats.

Limitations of the Study

In spite of its contribution to it, the research has certain limitations. The cross-sectional design inhibits the causal relationship that can be established between variables. The data obtained was grounded in self-reported questionnaires and it might be biased or inaccurate. University level athletes were only used as sample and this may be interpreted to imply that the results of this sample cannot be extended to the other populations such as elite and recreation athletes. Besides, medium size of samples could have hindered identification of the superior association among variables.

Future Research Directions

In order to obtain more intuitive understanding of causal relationship of training load, recovery, and risk of injury, the future study can be based on a longitudinal or experimental research design. The researchers are encouraged to include objective biological variables such as change in heart rates, hormonal variables, and biomechanical variables to make the outcomes more valid. It would be better in generalizability the research with more extensive and diversified samples on sports and levels of competitions. Besides this, we can propose that the other mediating/moderating variables, which comprise psychological pressure, the coaching method, and environmental variables can be considered in subsequent research.

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