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Original Research

Lower Extremity Alignment is a Risk Factor for Non-Contact Anterior Cruciate Ligament Injuries in Elite Male Wrestlers

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ABSTRACT

This study investigated the potential link between lower extremity alignment and Anterior Cruciate Ligament (ACL) injuries in elite male wrestlers. It was hypothesized that lower extremity alignment could predict ACL injury risk. Sixty male wrestlers, divided into injured (n=30) and non-injured (n=30) groups. Lower extremity alignment indices, including pelvic inclination, hip anteversion, quadriceps angle, knee hyperextension, tibial torsion, plantar arch index, and rear foot angle, were measured. Multiple logistic regression analysis was employed to identify predictor factors for ACL injuries. The results revealed that only the plantar arch index was a statistically significant predictor for non-contact ACL injuries in elite male wrestling athletes ($P<0.05$). Consequently, the findings suggest that focusing on distal variables of the knee may be crucial when designing ACL injury prevention programs.

Keywords: ACL injury, Lower extremity alignment, Non-contact injury, Elite wrestlers

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INTRODUCTION

Wrestling, an ancient and globally popular sport, has a rich history and widespread presence across various cultures. [1]. Wrestling is such a sport that needs extreme exercise programs placing intensive demands on the athlete's body, leading to high rates of injury relatively [2].

Wrestling brings a risk of injury across all ages and weight classifications [2, 3]. Shadgan et al. (2017) investigated wrestling injuries through an epidemiologic study among professional wrestlers during the 2016 Rio Olympic Games and found 22 injuries in 352 athletes in 410 matches. This result suggests that the rate was 6.2 injuries per 100 athletes among wrestlers and 5.4 injuries for every 100 matches, which were lower compared to the London 2012 (12%) and Beijing 2008 (9.3%) Olympic Games [4]. Yard and Comstock (2008 compared the injuries between the Freestyle wrestlers and Greco-Roman in the 2006 American National Championships and reported a total incidence of 5.8 per 1000 hours [5]. The prevalence of injuries to the Freestyle wrestlers was 7 injuries and to the Greco-Roman and Freestyle wrestlers was 4.6 injuries per 1000 hours [5]. The cost of wrestling injuries is expected to be more than $ 650 million per year in the United States [6].

ACL injuries are known as one of the most common injuries among athletes of all sports [7], and wrestlers have revealed a high prevalence accordingly [1, 8]. ACL injuries can be considered serious injuries and threaten the professional career of athletes, imposing a lot of costs on the health care system [9, 10]. In addition, many internal and external factors as risk factors for non-contact ACL injuries have been potentially identified and classified into different categories, such as anatomical, hormonal, environmental, and biomechanical [7]. Accordingly, one of the predisposing factors to ACL injuries is lower extremity malalignment [11]. In this regard, many studies reported the association of lower extremity malalignment with sports injuries [12, 13]. Further, in the literature, it has been well established that malalignments are associated with the risk of knee injuries among athletes, including foot hyper-pronation [14, 15], quadriceps angle (q-angle) [16, 17], leg length discrepancy [18, 19] and pelvic tilt [16, 19]. These malalignments have been linked with a higher risk of ACL injuries as they could put augmented stress on the ACL. As such, hyper-pronation is related to more tibial internal rotation, then a large q-angle would be related to greater knee valgus, and a discrepancy in the length of the leg may lead to hyper-pronation on the "short" leg, and pelvic obliquity might result in more hip internal rotation that all such variations have the potential to impact the ACL harmfully. However, the relationship between a set of lower extremity alignment variables has been addressed in very few investigations. Daneshmandi et al. (2011) studied the differences in lower extremity alignments among the participants with /without ACL reconstruction by comparing the navicular drop, T-F angle, anteversion, Q angle, hip internal and external rotation range of motion, knee recurvatum, and actual and apparent leg length. Their findings indicated significant differences between the two groups in pronation, T-F angle, Q angle, anteversion, and hip external rotation. As a result, it seems necessary to identify the factors (biomechanical and anatomical) that predispose individuals to ACL injuries [20]. Moreover, no consensus exists regarding the findings as if various research indicated that navicular drop is a predictive factor for ACL injuries [13, 16]. Additionally, the other studies failed to report any correlation between navicular drop and ACL injuries [21, 22].

To our knowledge, no research reported the association of lower extremity alignment with ACL injuries in elite wrestling athletes. Moreover, there are very few studies that assess the relationship between comprehensive sets of lower extremity alignment and ACL injuries as a single model. Also, no consensus exists regarding the issue. Therefore, the current study intended to evaluate whether lower extremity alignment could predict ACL injuries in elite male wrestlers.

MATERIAL AND METHODS

Study design

The measurments of the current retrospective study was conducted in a Biomechanics Research Laboratory, adhering to the pertinent guidelines of the Declaration of Helsinki. To ensure the highest standards of research ethics, the study received approval from the ethics committee of the Sport Sciences Research Institute of Iran. The reporting of this study strictly adheres to the 'Strengthening the Reporting of Observational Studies in Epidemiology' (STROBE) guideline [23].

Participants

60 male wrestlers aged 20-30 years (divided into 30 injured and 30 non-injured) voluntarily participated in this study. Prior to assessment, all participants signed an informed consent form. Demographic data, including age (mean: 27.5 ± 2.2 years), height (mean: 181.7 ± 7.7 cm), and weight (mean: 85.6 ± 14.5 kg), were collected (Figure 1).

Eligibility criteria for participannts included a history of participation in the Iranian wrestling premier league within the last five years. Wrestlers with a history of injury were considered if they experienced a non-contact anterior cruciate ligament (ACL) rupture (grade III), confirmed by magnetic resonance imaging (MRI) and a medical committee. Participants were included in the study if they had no ACL reconstruction during the 6-24 months following the injury.

Procedure

Prior to data collection, acceptable reliability for all lower extremity alignments was established. To determine intra-tester reliability for lower extremity alignment, assessments were conducted for ten participants on two separate days, with a one-week interval between evaluations. The test-retest reliability for all variables demonstrated excellence (intraclass correlation coefficient: 0.84 to 0.98), ensuring high consistency in the measurements.

The same examiner carried out the clinical measures of the lower extremity in the injured leg (the ACL rupture). Pelvic inclination was assessed using an inclinometer featuring two caliper arms. The validity of these measurements was found to be substantial when compared to the results obtained through radiograph measurements [24]. To conduct this assessment, the subject stood comfortably with their feet spaced approximately 10-12 cm apart. The examiner identified the prominent areas of the ipsilateral Anterior Superior Iliac Spine (ASIS) and Posterior Superior Iliac Spine (PSIS) through palpation, and marked these points with a pen. The caliper tips were then employed to measure the sagittal plane rotation of the innominate bone relative to the marked ASIS and PSIS points. Positive values (+) indicated an anterior pelvic tilt angle, while negative values (-) represented a posterior pelvic tilt angle [25].

To evaluate hip anteversion, the assessor conducted Graig's test with the subject in a prone position, maintaining a 90-degree knee flexion. The examiner palpated the posterior portion of the greater trochanter and aligned it parallel to the examination table. Subsequently, the subject's hip was passively rotated. The anteversion angle of the hip was then recorded, using the vertical line as a reference and the shaft of the tibia as a reference point for the subjects [26, 27].

The Q angle was established by positioning the goniometer's axis directly over the patella's center. Subsequently, the value was obtained by drawing two lines: one from the anterior superior iliac spine (ASIS) to the patella's center, and the other from the patella's center to the tibial tuberosity [28].

The knee hyperextension was measured by positioning the goniometer's center on the femoral epicondyle in a standard standing posture. The goniometer's arms were aligned parallel to the hip's greater trochanter and the central line of the tibia's lateral section. Subsequently, the fixed angle was documented [26, 29].

To assess tibial torsion, the tight-foot method was employed. The subject was positioned prone on a table with the knee flexed at a 90-degree angle. To record the value, the center of the heel was marked on the plantar surface of the foot. Subsequently, two lines were drawn: one connecting the heel center to the middle of the foot, and another dividing the hip into two equal halves [26].

The plantar arch index was determined through the navicular drop test, which evaluates the medial longitudinal arch's function by measuring height differences of the navicular tuberosity in sitting and standing positions. To measure navicular drop, a subject in a fully weight-bearing position with talar head congruency was employed. The distance between the navicular tuberosity and the supporting surface was noted. After ensuring the subject's relaxation, a ruler was used to quantify the sagittal plane excursion of the navicular in the test [30].

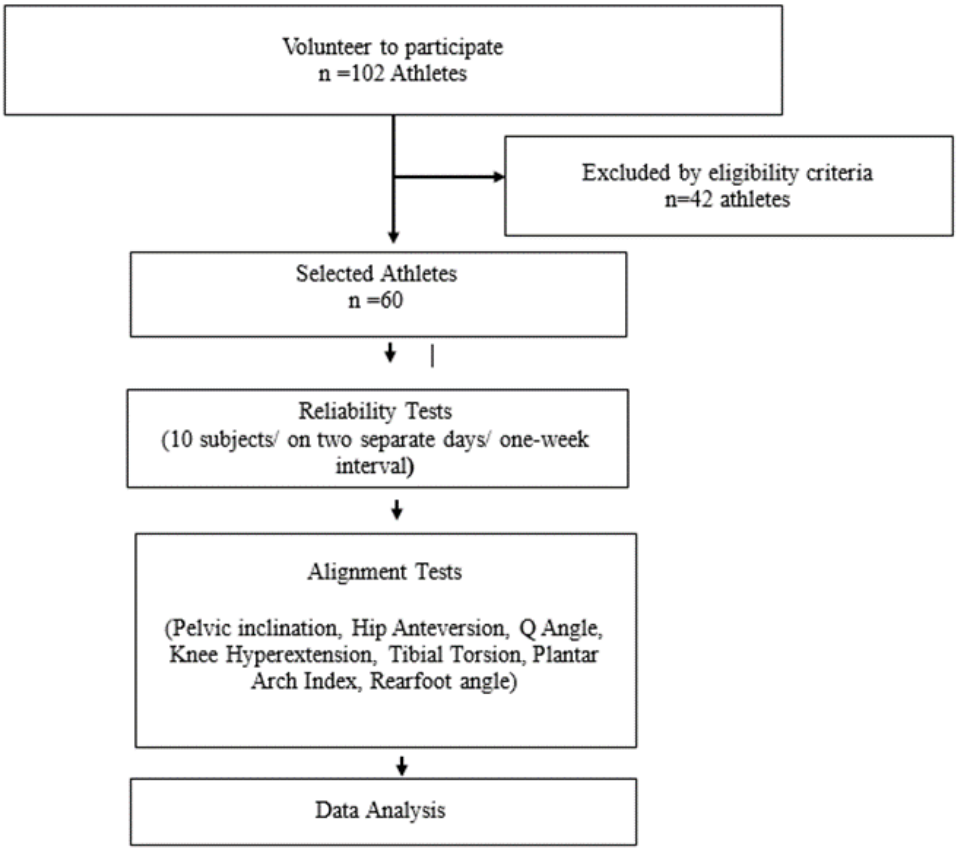

Figure 1. The flow of study

For rearfoot angle measurement, subjects were asked to stand barefoot in a normal posture. The angle was determined using a manual goniometer, which involved marking a line that divided the posterior calcaneus and the lower one-third of the shank. The recorded value represented the rearfoot angle in this context [31, 32].

Statistical Analysis

Descriptive data are presented by mean and standard deviation (M±SD). A significant difference was considered when $p<0.05$. All statistical analyses were conducted using SPSS statistical software (version 20) from Chicago, Illinois. To examine the predictive factors for ACL injuries, a multiple logistic regression analysis was employed. The variance inflation factor (VIF) was considered to assess the severity of multicollinearity between independent variables. VIF values ranging from 1.21 to 2.9 were acceptable, while VIF>5 indicated a potential multicollinearity issue [33].

RESULTS

The study results showed that the plantar arch index was the only lower extremity alignment variable that significantly predicted ACL injuries ($p < 0.05$). The plantar arch index had a positive and significant effect on ACL injuries, with a 95% confidence interval of (0.077–0.246) and an odds ratio of 0.76 ($p = 0.001$, $B = 0.16$). This indicates that for every 1 mm increase in the plantar arch index, the probability of experiencing ACL injuries would rise by 0.6 times (Table 1).

Table 1. Results of multiple logistic regression analysis for ACL injury

Dependent Variable	Potential Factors	Unstandardized Coefficients	P-value	Standardized Coefficients	95% Confidence Interval	
					Lower Bound	Upper Bound
ACL[b] Injury	Constant	-0.319	0.64		-1.731	1.092
	Pelvic Inclination	0.021	0.72	0.52	-0.102	0.144
	Hip Anteversion	0.065	0.19	0.173	-0.36	0.167
	Q Angle[c]	-0.014	0.59	-0.087	-0.68	0.040
	Knee Hyperextension	0.071	0.29	0.177	-0.65	0.207
	Tibial Torsion	-0.015	0.58	-0.094	-0.072	0.042
	Plantar Arch Index	0.16	0.001[a]	0.605	0.077	0.246
	Rearfoot Angle	0.05	0.19	0.221	-0.03	0.139

[a.]Statistically significant associations were observed using a multiple logistic regression model
[b]: Anterior Cruciate Ligament
[c:] Quadriceps Angle

DISCUSSION

The main objective of the study was to examine the relationship between lower extremity alignment and non-contact ACL injuries in elite male wrestlers. The findings revealed that only one variable, the plantar arch index, served as a predictor of ACL injuries among the seven lower extremity alignment variables in this specific population. The results suggest a significant association between the plantar arch index and ACL injury incidence, with an increased plantar arch index leading to a 0.6 times higher probability of experiencing ACL injuries in elite wrestlers.

According to the kinematic chain concept, there exists a connection between foot pronation and a reduced plantar arch, which may result in internal tibia rotation [34]. This relationship implies that individuals with lower plantar arch indices might be more prone to internal tibia rotation, potentially increasing their risk of ACL injuries. Previous research has indeed highlighted that excessive internal tibia rotation, often resulting from foot pronation, can contribute to the occurrence of ACL ruptures. This information further emphasizes the importance of considering lower extremity alignment, including the plantar arch index and foot pronation, in understanding and preventing ACL injuries [14, 35]. It is also crucial to note that foot pronation in conjunction with limited ankle dorsiflexion can contribute to the development of faulty movement patterns, such as dynamic knee valgus. This movement pattern is often associated with ACL injuries [36]. Also,Limited ankle dorsiflexion can indeed have a significant impact on an individual's movement during activities that involve deceleration or rapid changes in direction. When ankle dorsiflexion is restricted, the forward progression of the tibia may be limited. This can lead to compensatory frontal plane knee excursion, which in turn results in increased knee valgus during functional tasks. Knee valgus is a movement pattern characterized by the knees coming together and the knees moving inward, placing excessive stress on the knee joint and increasing the risk of ACL injuries [37]. It is essential to recognize the relationship between limited ankle range of motion, particularly ankle dorsiflexion, and its impact on knee flexion range of motion and ground reaction forces. When ankle dorsiflexion is restricted, it can lead to less knee flexion range of motion. Consequently, this may result in greater ground reaction forces during various physical activities. These increased ground reaction forces can cause the lower extremity to deviate into a more knee valgus position, which is associated with a higher risk of ACL injuries [38]. Researchers have indeed proposed that increased ground reaction forces, significant valgus displacement, and reduced

knee flexion range of motion during functional activities like landing tasks can potentially increase the likelihood of ACL injuries. When an individual lands from a jump or performs other activities that involve rapid deceleration, the combination of these factors can place excessive stress on the knee joint, particularly the ACL. This stress may lead to overloading the ACL, ultimately resulting in injury [7, 30, 38].
n the context of wrestling, where athletes perform various functional movements like cutting and jumping maneuvers while focusing on their opponents, foot pronation can be a concern. Pronation may lead to dynamic knee valgus or anterior tibial translation, increasing the risk of ACL injuries. While other lower extremity variables might not directly predict ACL injuries, there is a theoretical association between excessive Q angle and increased knee valgus deviation. This association may contribute to ACL injuries, as the knee is displaced medially more in the frontal plane [39]. In addition to foot pronation, rearfoot eversion is another factor that can contribute to the risk of ACL injuries in wrestlers. Rearfoot eversion leads to tibial abduction, which in turn increases the strain on the ACL. This places the ACL in a higher-risk position for potential injuries [40].

It is essential to recognize that ACL injury incidence is influenced by a complex interplay of various factors, including internal factors, such as shoe/surface interface [41, 42], knee bracing [43], ambient temperature and weather [44], neuromuscular control-related and biomechanical factors [45], and even psychological and mental factors [46, 47] could contribute to ACL injuries. Since many risk factors lead to ACL injuries, To design effective ACL injury prevention programs, it is crucial to acknowledge and address the multifaceted nature of these risks. Incorporating strategies that target all relevant factors can lead to a more comprehensive and holistic approach to injury prevention. This may involve elements like proper footwear and surface selection, utilizing knee braces when necessary, considering environmental factors, enhancing neuromuscular control and biomechanics through targeted exercises, and addressing psychological factors that may impact performance and injury risk.

By acknowledging the various factors that contribute to ACL injuries and understanding these biomechanical relationships can help in developing targeted injury prevention strategies and interventions for athletes and other individuals engaged in activities that put stress on the lower extremities. incorporating them into prevention programs, wrestlers can better manage their overall risk and improve their chances of maintaining a healthy, injury-free athletic career.
It is essential to recognize the limitations of the study and its methodology when interpreting the findings. One such limitation is the potential inconsistency in measuring static alignment of the lower extremities through clinical methods. This could be due to various factors, such as the subjectivity of human observation, variability in the examiner's experience, or the inherent difficulty in accurately assessing static alignment in a clinical setting.
While a good Intraclass Correlation Coefficient (ICC) was reported in the study, this does not guarantee complete accuracy or consistency in the measurement of lower extremity alignment. The limitations of clinical methods should be considered when applying the study's findings to real-world situations.
To overcome these limitations, researchers may consider incorporating advanced technology, such as motion capture systems or 3D imaging techniques, to objectively and more accurately assess lower extremity alignment. By doing so, they can potentially improve the reliability and validity of their findings, leading to more effective injury prevention strategies and interventions.
In conclusion, the study highlights the importance of the plantar arch index as a significant predictor of non-contact ACL injuries among elite male wrestling athletes. This finding emphasizes the need for clinicians and coaches to adopt a comprehensive approach when designing prevention programs, taking into account all potential contributing factors to ACL injuries.
By acknowledging the role of the plantar arch index and incorporating it into injury prevention strategies, professionals can better address the multifaceted nature of ACL injury risk. This may involve targeted interventions to improve lower extremity alignment, such as orthotics or specific exercises to strengthen the foot and arch, alongside addressing other factors like neuromuscular control, biomechanics, and environmental influences.

In summary, understanding the significance of the plantar arch index in predicting non-contact ACL injuries can contribute to more effective injury prevention efforts and ultimately help maintain the health and performance of elite male wrestling athletes.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data will be available at request.

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راستای اندام تحتانی یک عامل خطرزا برای بروز آسیب های غیربرخوردی رباط صلیبی قدامی در کشتی گیران مرد نخبه

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چکیده: راستای اندام تحتانی به عنوان یک عامل خطرزا برای آسیب های رباط صلیبی قدامی در کشتی گیران در نظر گرفته می شود. اما اتفاق نظری در خصوص نحوه ارتباط بین این فاکتورهای و آسیب رباط صیلبی وجود ندارد. از اینرو هدف مطالعه حاضر این مورد است که آیا راستای اندام تحتانی می تواند بروز آسیب رباط صلیبی در کشتی گیران حرفه ای را پیش بینی کند.

۶۰ کشتی گیر(۳۰ آسیب دیده و ۳۰ نفر سالم) به صورت گذشته نگر وارد تحقیق حاضر شدند. راستای لگن، آنتی ورژن ران، زاویه Q، هایپراکستنشن زانو، چرخش تیبیا، شاخص قوس کف پا و شاخص ولگوس پاشنه به عنوان فاکتورهای راستای اندام تحتانی مورد بررسی قرار گرفتند. برای شناسایی فاکتورهای پیش بینی کننده آسیب رباط صلیبی قدامی از روش آماری رگرسیون لوجستیک چندگانه استفاده شد. در میان تمامی متغیرهای بررسی شده تنها شاخص قوس کف پا به صورت معناداری بروز آسیب رباط صلیبی را پیش بینی کرد($P<0.05$). به نظر می رسد برای طراحی پروتکل های پیشگیری از آسیب رباط صلیبی قدامی باید فاکتورهای دخیل در اندام های پایین تر از مفصل زانو نیز، مد نظر قرار گیرند.

واژه‌های کلیدی: آسیب رابط صلیبی، راستای اندام تحتانی، آسیب های غیر برخوردی، کشتی گیر نخبه.