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Study of The Effect of Fatigue Level on Reducing the Injury Level in Netball Players

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ABSTRACT

Athletic performance is often affected by fatigue, which can significantly impact neuromuscular function, power output, and overall movement efficiency. Chronic ankle instability orChronic Ankle Instability (CAI)This is a common condition, particularly among athletes, including netball players. It causes structural and functional impairments, such as ligament laxity and weakened muscle support around the joint.Objective this study aimed to analyze the effects of a fatigue-inducing protocol on jump height, peak power, peak velocity, and reaction time in netball players. The research method used a quantitative pre-posttest design with retrospective data analysis. This study used a fatigue protocol to simulate game-like conditions and analyze performance. *Counter Movement Jump* (CMJ) before and after fatigue using SPSS software. Paired sample t-tests and correlation analyses were performed to assess performance changes. The results showed that although peak velocity did not show statistically significant changes after fatigue, both peak power and jump height decreased significantly, and fatigue impacted lower limb explosive performance. The difference in jump height with fatigue testing before and after the intervention was statistically significant ($p<0.001$) indicating a significant change in jump height after the fatigue protocol. Correlation analysis showed that there was no significant relationship between CAI and fatigue-induced performance decline.In conclusion, There is a significant effect of fatigue levels on reducing injury rates in netball players.

Keywords:

Fatigue, Injury, Netball Player.

1. INTRODUCTION

Chronic ankle instability is a common condition among young athletes, particularly in sports that require frequent jumping and landing, such as netball. CAI (*Chronic Ankle Instability*often occurs because of repeated ankle sprains, leading to impaired proprioception, decreased dynamic balance, and reduced performance (Attenborough et al., 2014). Young netball players with CAI face challenges in maintaining functional stability during high-impact activities, which increases their risk of injury (Attenborough et al., 2017).

Fatigue exacerbates the detrimental effects of CAI on performance and increases susceptibility to injury. Studies (Mohamadi et al., 2022; Muhammad et al., 2023; Kowalczyk & Truszczyńska-Baszak, 2024) have shown that muscle fatigue can lead to decreased jump height and slower reactions, significantly impairing performance.*Counter Movement Jump*(CMJ) and dynamic stability in athletes with CAI. This fatigue-related decline is particularly concerning in young athletes, whose physical and neuromuscular systems are still developing.

Netball players frequently perform CMJs during matches, that are integral to both defensive and offensive maneuvers. Effective jumping performance requires precise neuromuscular coordination, which is impaired in athletes with CAI. Previous research has examined the impact of general fatigue on athletic performance, including endurance, reaction time, coordination, and strength, but has not adequately explored the specific influence of fatigue on CMJ performance in netball players with CAI (Taylor et al., 2020). Muhammad et al. (2023) reported detrimental effects of fatigue on jumping mechanics and dynamic balance, demonstrating that lower limb muscle fatigue significantly reduced CMJ height and postural stability in elite young netball players with CAI. Kowalczyk and Truszczyńska-Baszak (2024) suggested that fatigue-induced decreases in stability were more pronounced in athletes with underlying ankle pathology. Collings et al. (2020) revealed that a netball-specific fatigue protocol induces biomechanical changes that increase the risk of landing injury. Jaiyesimi (2018) also studied the effects of fatigue on single-leg landing performance and showed that fatigued players experienced slower muscle activation and decreased proprioception, which increased the risk of further ankle instability. These findings emphasize the need for specific conditioning programs to counteract the detrimental effects of fatigue on CMJ performance in netball players with CAI.

Biomechanical factors such as foot position and joint angles can influence the risk of injury and performance in netball. McKenzie (2019) showed that implementing a structured warm-up protocol improves vertical jump performance and reduces injury rates in young netball players. However, the interaction between CAI, fatigue, and CMJ performance, as well as the significant impact of fatigue on lower limb muscle performance, remains unexplored, creating a gap in the literature.

Although the impact of CAI on athletic performance is well recognized, few studies have quantitatively analyzed how fatigue alters CMJ performance in young netball players with CAI. This lack of data significantly hampers the development of targeted interventions aimed at reducing injury risk and improving the performance of young netball players with CAI. Addressing this critical gap is crucial for developing evidence-based strategies that optimize athletic training and rehabilitation practices for young netball players with CAI. This study aimed to provide insights into the specific neuromuscular vulnerabilities of young netball players with CAI, potentially improving player safety through targeted training and enhancing performance through personalized interventions (Thomas et al., 2021).

The findings of this study will inform the design of targeted training programs aimed at mitigating fatigue-related performance decline and offering tailored solutions to enhance athletic performance and reduce injury risk. Furthermore, this study will aid in the development of rehabilitation protocols that address the unique challenges posed by CAI and improve long-term athletic health (Belcher et al., 2020). This study will also enhance the understanding of how fatigue influences injury mechanisms and elucidate the interplay between neuromuscular fatigue and injury risk in youth sports. The findings of this study are expected to contribute to improved training methodologies, reduced injury risk, and advance the development of science and practice in youth sports. Objective. To evaluate fatigue-inducing protocols that affect CMJ performance in netball players with CAI.

2. METHOD

A retrospective quantitative study was designed to examine the effects of fatigue on jumping performance after a counter movement jump (CMJ) in young static netball players with chronic ankle instability (CAI). A retrospective approach was chosen to utilize previously recorded data obtained in a controlled experimental setting. This method reduces the participant burden while maintaining data accuracy and reliability. This approach analyzes pre existing data, allowing for a comprehensive evaluation of the relationship between fatigue and jumping mechanics in athletes with CAI. Data analysis was performed using a paired sample test method.

Participants

Participants were recruited from the National Sports School in Malaysia in 2023 using purposive sampling. Participants were selected according to the following inclusion and exclusion criteria.

Inclusion Criteria:

1. Young female netball players (aged 13-20 years)
2. At least one ankle sprain results in symptoms, such as swelling, pain, and temporary loss of function.
3. The initial sprain occurred at least 12 months prior, and the most recent injury occurred more than three months prior to enrollment.
4. Cumberland Ankle Instability Tool (CAIT) score less than or equal to 24.

The exclusion criteria consisted of the presence of musculoskeletal and medical conditions that could limit independent ambulation and full participation in the study. A power analysis using G*Power was performed to determine the recommended minimum sample size of 30 for a 0.9 statistic, alpha level of 0.05, and effect size of 0.25, to ensure statistical reliability. All participants followed the same training and competition schedule to ensure consistency, and attended netball-specific training sessions five days a week, which included skill development, tactical drills, and physical conditioning. In addition, they participated in at least one competitive match per week.

Ethical Considerations

This study was conducted using pre-existing data, ensuring no new data collection or direct involvement of the participants. Ethical approval was obtained from the Institutional Ethics Committee prior to data access and analysis. To maintain confidentiality and privacy, all participant data were anonymized, and no identifying information was included in the analysis or reporting. The data were stored securely and used for research. Because this was a retrospective study, informed consent was obtained.Written (informed consent) was not required from the participants, as data had previously been collected based on ethical approval for research purposes.

Instrumentation or Measurement of Results

The severity of functional ankle instability was evaluated using the CAIT, a self-report questionnaire designed to assess three key aspects of ankle instability: functional, mechanical, and perceived instability. The questionnaire consisted of nine items aimed at diagnosing and providing insight into the severity of CAI, each rated on a scale of 0 to 6, with a maximum score of 30. The CAIT allows for objective identification of a homogeneous group of participants, facilitating comparisons within the study. Participants with at least moderate functional ankle instability were classified based on a CAIT score of less than 24 (Gribble et al., 2004). The CAIT is a reliable and valid tool for assessing chronic ankle instability. The reliability of the CAIT test is excellent (intraclass correlation coefficient, ICC = 0.86), with high accuracy in identifying CAI >90% (Rosen et al., 2021). The sensitivity and specificity of the CAIT are approximately 80.7% and 84.9%, respectively, with a cutoff score of <24 considered good (Li et al., 2021). Netball players with a history of ankle sprains were asked to complete the CAIT form, and only those exhibiting symptoms of CAI were be selected for additional testing.

3. RESULTS AND DISCUSSION (10 PT)

Respondent description

Table 1. Descriptive Statistics

Variables	N	Minimum	Maximum	Mean	Std. Dev.
Age	34	13.00	19.00	15.2647	1.63871
Weight	34	51.80	82.50	68.0765	9.67318
Height	34	162.00	183.00	171,8794	5.70910

The demographic characteristics of the study participants (N = 34) are shown in Table 1. Participants' ages ranged from 13 to 20 years, with a mean age range of 15.2 years (SD = 1.63). This indicates that the sample primarily consisted of adolescents in the developmental stage. Participants' body weight varied between 51.8 kg and 82.5 kg, with a mean of 68.07 kg (SD = 9.67). This variability in body weight reflects differences in body composition among young netball players. Similarly, the participants' height ranged from 162 to 183 cm, with a mean of 171.8 cm (SD = 5.70). The relatively small standard deviation of the height indicates that the sample was homogeneous in terms of height.

Table 2. Changes in Peak Velocity, Peak Power and Jump Height

	Mean	Std. Dev.	95% Confidence Interval of Difference		t	df	Sig. (2-tailed)
			Lower	Upper			
Pre PV – post 5 PV	.160471	.566145	-.037067	.358008	1,653	33	.108
Pre PP – post 5 PP	316.6971	731.9246	61.3165	572.0776	2,523	33	.017
Pre Jump – Post 5 Jump	.020353	.027756	.010668	.030038	4,276	33	.000

The measurement results for the changes in peak velocity, peak power, and jump height are listed in Table 2. The average difference in the peak power before and after the fatigue protocol was 316.69 with a standard deviation of 731.92 and a mean standard error of 125.52. The 95% confidence interval for this difference ranged from 61.3165 to 572.0776. The t-value was 2.523, with 33 degrees of freedom, and the significance level (2-tailed) was 0.017. The difference in the peak power before and after the protocol was statistically significant ($p<0.05$), indicating a significant change in the peak power after the fatigue protocol. The average difference between the jump height before and after the fatigue protocol with the fatigue test was 0.0203, with a standard deviation of 0.0277 and mean standard error of 0.0047. The 95% confidence interval for this difference ranged from 0.0106 to 0.0300. The t-value was 4.276, with 33 degrees of freedom, and the significance level (2-tailed) was 0.000. The difference in jump height in the fatigue test before and after intervention was highly statistically significant ($p<0.001$), indicating a significant change in jump height after the fatigue protocol.

Table 3. Correlation of Ankle Instability Severity with Peak Velocity

		Mean diff. PV
Mean diff. PV	Pearson Correlation	1
	Sig. (2-tailed)	
	N	34
CAIT	Pearson Correlation	.008
	Sig. (2-tailed)	.963
	N	34

Based on Table 3, the measurement results kThe Pearson correlation coefficient between the CAIT and peak velocity showed a mean difference of 0.008. This value indicates a very weak positive correlation between CAIT scores and the mean difference in peak velocity due to fatigue. The significance values (Sig. 2-tailed) for the correlation between CAIT and mean difference was 0.963. This value was much greater than the conventional threshold of 0.05, indicating that the correlation was not statistically significant. Correlation analysis showed that there was no significant relationship between CAI and fatigue-induced performance decline.

Table 4. Correlation of Ankle Instability Severity with Peak Power

		Mean diff. PP
CAIT	Pearson Correlation	-.030
	Sig. (2-tailed)	.865
	N	34
Mean diff. PP	Pearson Correlation	1
	Sig. (2-tailed)	
	N	34

Based on Table 4 that the Pearson correlation coefficient between thw CAIT and the mean difference was -0.030. This value indicates a very weak negative correlation between CAIT scores and the mean difference in peak power due to fatigue. The significance values (Sig. 2-tailed) for the correlation between CAIT and mean difference was 0.865. This value was much greater than the conventional threshold of 0.05, indicating that the correlation was not statistically significant. Correlation analysis showed that there was no significant relationship between CAI and fatigue-induced performance decline.

Table 5. Correlation of Ankle Instability Severity with Jump Height

		Mean diff. Jump
CAIT	Pearson Correlation	.018
	Sig. (2-tailed)	.922
	N	34
Mean diff. Jump	Pearson Correlation	1
	Sig. (2-tailed)	
	N	34

Based on Table 5, the Pearson correlation coefficient between the CAIT jump height and mean difference was 0.018. This value indicates a very weak positive correlation between CAIT scores and the mean difference in jump height due to fatigue. The significance values (Sig. 2-tailed) for the correlation between CAIT and mean difference was 0.922. This value was much greater than the conventional threshold of 0.05, indicating that the correlation was not statistically significant. The correlation analysis shows that there is no significant relationship between the CAI and performance decline due to fatigue.

Discussion

This study revealed that peak velocity at the CMJ was largely unaffected by fatigue in young netball players with CAI. Previous research by Muhammad et al. (2023) showed that those with CAI may develop compensatory neuromuscular strategies to maintain jumping performance, even when fatigued. This adaptation may explain why the peak velocity remains maintained, even though other factors such as jump height or power, may decrease. Neuromuscular control may prioritize movement speed over force output, allowing peak velocity at the CMJ to remain consistent despite fatigue.

Several studies have identified compensatory movement adaptations in individuals with CAI, which may explain the maintenance of peak velocity despite a decreased jump height or power. McKenzie (2019) reported that athletes with CAI exhibit altered lower limb kinematics and muscle activation patterns, which may contribute to sustained movement efficiency even under fatigued conditions. Similarly, Gamble (2011) suggested that neuromuscular compensation, such as increased reliance on proximal muscle groups (e.g., hip and knee extensors), may help offset ankle stability deficits, allowing for movement continuity.

A key mechanism in compensatory adaptation is a shift in the neuromuscular control strategy. Sebesi et al. (2021) found that athletes with CAI may prioritize movement speed over force generation, allowing them to maintain fast takeoff mechanics at the CMJ, while sacrificing force output and jump height. This may explain why the peak velocity remained stable, even as the power and height decreased under fatigue.

Fatigue is known to reduce lower limb force production and neuromuscular efficiency, ultimately impairing power output and jump height. A study by Muhammad et al. (2023) found that fatigue-induced neuromuscular changes significantly reduced peak power, peak force, flight time, and jump height performance in netball players with CAI, as these athletes experienced greater postural instability and reduced muscle activation than their healthy peers. McErlain-Naylor et al. (2014) emphasized that joint angular velocity and coordination are important determinants of CMJ performance, and fatigue impairs these factors, leading to an impaired jump height.

Furthermore, Boullosa et al. (2018) examined the relationship between the Rate of Force Development (RFD) and fatigue in CMJ performance, and found that fatigue significantly reduced the rate of force development, thus impairing peak power output. This is because fatigued muscles take longer to reach the peak force, resulting in suboptimal power production. Muhammad et al. (2023) also observed that fatigue causes a delay in muscle activation time, which impacts force application during explosive movements, such as jumping. The findings of this study align with these results, as netball players with CAI showed significant decreases in force-based jump metrics after fatigue. Sanders et al. (2025) found that fatigue disproportionately impacts peak power and jump height in athletes with pre-existing lower limb instability, suggesting that neuromuscular compensation in athletes with CAI is insufficient to fully overcome fatigue-induced impairments.

Fatigue not only reduces the muscle power output but also alters the biomechanics of jumping. Dyke (2023) showed that fatigue impairs force production and reduces the efficiency of the Stretch-Shortening Cycle (SSC), which is essential for generating peak power at the CMJ. Furthermore, Collings et al. (2020) found that netball players adoptedncompensatory movement patterns when fatigued, including reduced knee flexion, altered takeoff mechanics, and inefficient force transmission, all contributing to reduced jumping performance.

These biomechanical changes are exacerbated in patients with CAI. Mullally and Clark (2021) noted that athletes with CAI exhibit decreased proprioception and joint stiffness, making them more susceptible to postural instability and fatigue-related power loss. This aligns with the findings of the current study, in which jump height and peak power were significantly impaired post-fatigue, reinforcing the role of CAI in exacerbating the fatigue-related performance decline. This study investigated the correlation between the CAI and fatigue-related CMJ decline. The findings did not demonstrate a significant correlation between CAIT scores and post-fatigue performance decline. This suggests that CAI severity does not directly predict fatigue-related declines in CMJ performance metrics.

One possible explanation for this lack of significant correlation is that athletes with CAI develop compensatory movement strategies that help maintain certain aspects of jumping performance during fatigue. Muhammad et al. (2023) found that although peak force and jump height decreased in netball players with CAI after fatigue, the peak velocity remained unaffected. This suggests that skilled athletes may utilize altered biomechanics to maintain velocity, despite reduced force output.

CAIT is a widely used assessment tool for self-reported ankle instability, but it may not fully capture the dynamic movement impairments that occur under fatigue. Kim et al. (2020) found that changes in center of pressure (COP) velocity correlated poorly with post-fatigue CAIT scores. This finding suggests that the effect of functional fatigue on CAI is not always proportional to the degree of self-reported instability. Rosier (2022) reported that athletes with lower CAIT scores do not necessarily experience greater declines in CMJ performance due to fatigue. This suggests that some performance declines are influenced by multiple biomechanical and neuromuscular factors, not just by the severity of CAI.

The findings of this study provide valuable insights into the impact of CAI and fatigue-induced jump performance on young netball players, particularly those in static positions, where explosive movements are crucial. The significant reduction in peak power and jump height following fatigue, coupled with the lack of correlation between CAI and performance decline, suggests that CAI severity alone does not fully determine functional impairment in netball-specific movements. These findings emphasize the importance of neuromuscular training, fatigue management, and individualized rehabilitation programs to improve performance and reduce the risk of injury.

Given that CAI severity alone does not fully predict fatigue-related performance impairment, rehabilitation programs for netball players should focus on dynamic movement assessment rather than solely relying on CAIT scores. Functional strength assessments, such as weighted lunges, bulgarian split squats, and weighted jumps, can improve lower limb stability and neuromuscular efficiency, thereby reducing the impact of fatigue on performance. Furthermore, fatigue-induced balance training should be incorporated into rehabilitation programs, with netball players with CAI performing balance exercises immediately after intense PA. This exercise mimics the fatigue conditions of real-life play, helping improve joint stability and proprioceptive awareness under pressure.

External support methods, such as ankle taping or bracing, can provide additional support during training and competition, especially for athletes recovering from ankle injuries. However, althought these methods can help reduce excessive ankle motion and increase confidence, they should be combined with proprioceptive retraining exercises to ensure long-term improvement in neuromuscular function.

Another limitation of this study is the sample size and its potential impact on generalizability. This study focused specifically on a group of young netball players, which may limit the applicability of the findings to athletes from other sports, different age groups, or different levels of competition. A larger and more diverse sample would improve the external validity of the results and provide a broader understanding of how the CAI affects jumping performance across different populations.

Furthermore, this study assessed jumping performance under static conditions, which do not fully account for the effects of fatigue during actual gameplay. In real-life game scenarios, players experience levels of fatigue that can affect their jumping mechanics and overall performance. As a result, the findings of this study may not fully reflect how CAI affects jumping ability under dynamic, match-like conditions.

The potential for measurement bias is another factor that should be considered. Although jump performance data were collected using force plates and motion analysis, small variations in individual jump execution and biomechanics may have introduced some degree of measurement errors. Furthermore, potential human error in data collection and analysis could have contributed to slight inconsistencies in the results.

Despite these limitations, the findings of this study contribute to existing knowledge on the impact of CAI on young netball players. To expand this research, future studies should consider using a prospective design, incorporating a larger and more diverse sample, and assessing jumping performance under fatigue or in-game conditions. Integrating biomechanical and neuromuscular assessments could further elucidate the mechanisms by which CAI affects jumping ability. By addressing these limitations, future research could provide stronger evidence and deeper insights into the complexities of the CAI and its impact on athletic performance.

4. CONCLUSION

Demographic characteristics of the participants showed that their ages ranged from 13 to 20 years, with a mean age range of 15.2 years (SD = 1.63), and their weights varied between 51.8 kg and 82.5 kg, with a mean of 68.07 kg (SD = 9.67). The difference in jump height in the fatigue test before and after the intervention was statistically significant ($P<0.001$), indicating a significant change in jump height after the fatigue protocol. Correlation analysis showed that there was no significant relationship between the CAI and performance decline due to fatigue. These findings contribute to the growing body of knowledge on sports-related ankle instability and emphasize the need for early intervention strategies in young athletes to maintain competitive performance levels while ensuring long-term joint health.

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While this study provides valuable insights into the effects of CAI on the jumping performance of young static netball players, several areas require further exploration. These findings analyze the key performance deficits and biomechanical changes associated with CAI, necessitating further research into the complexities of CAI and its impact on athletic performance. we thank the Faculty of Health Sciences, MARA University of Technology, and all the parties involved in this research program.

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