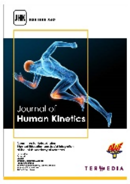

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Section I – Kinesiology

Acute Effects of Visual Information Blocking during the Pre-Set on Drop Jump Performance, Lower Limb Kinematics and Kinetics

by
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This study investigated how visual information blocking influenced drop jump (DJ) performance and lower limb mechanics, with a specific focus on its impact on stretch-shortening cycle (SSC) efficiency and neuromuscular adaptation in plyometric training. Fourteen male students (age: 22.0 ± 2.2 years; body height: 174.8 ± 2.4 cm; body mass: 70.3 ± 4.8 kg) performed DJs from a 0.3 m platform under normal and blind conditions. The DJ-index (jump height/contact time), joint kinematic and kinetic variables were measured. The blind condition resulted in a significantly lower DJ-index ($p < 0.001$*) and longer contact time (*$p < 0.001$*), while jump height remained unchanged. Knee flexion (*$p = 0.028$*), hip flexion (*$p = 0.014$*), and knee extension (*$p = 0.046$*) increased significantly. Peak (*$p = 0.011$*) and mean (*$p = 0.006$*) ground reaction forces, as well as ankle joint kinetics were lower under blind condition. These results suggest that visual feedback enhances SSC efficiency by regulating lower limb joint movement and force production. Without visual input, increased joint flexion compensates for reduced ankle force exertion, leading to longer contact times. These findings suggest that while visual information blocking decreases SSC efficiency, explosive power can be maintained through biomechanical adjustments.*

Keywords*: plyometric training; stretch-shortening cycle; sensory motor; temporal-spatial prediction; assessment*

Introduction

Athletic movements such as sprinting, change of direction, and jumping rely heavily on the stretch-shortening cycle (SSC) of the lower limbs to maximize performance efficiency (Komi, 2003). Among plyometric exercises, the drop jump (DJ) or the rebound jump serves as both a tool for enhancing explosive power and reliable assessment of SSC efficiency (Yoshida et al., 2024; Zushi et al., 2022, 2023). Recent studies employing kinetic and kinematic analyses of lower limb joints during takeoff have refined the evaluation of SSC mechanics across different athletic populations (Yoshida et al., 2024; Zushi et al., 2022).

The successful execution of the DJ depends on the ability to predict the landing timing of athletes (Zushi and Takamatsu, 1995). This enables athletes to utilize the stretch load induced by falling to generate substantial power during takeoff (Komi and Gollhofer, 1997; Leukel et al., 2012; Taube et al., 2012a). Specifically, by performing appropriate pre-activation and lower limb muscle flexion initiation movement (Taube et al., 2012a; Zushi and Takamatsu, 1995) before landing, athletes can withstand ground reaction forces exceeding 10 times their body weight immediately after landing and suppress excessive flexion of the knee and hip joints (Yoshida et al., 2024). In addition, after ground contact, stretching the lower limb muscles facilitates the stretch reflex (Komi and Gollhofer, 1997; Leukel et al., 2012; Nicol et al., 2006) and storage of elastic energy (Böhm et al., 2006). This enables rapid and large power exertion over a short period of time, suppressing negative power in the knee and hip joints and enabling power and torque exertion in the ankle joints and positive power exertion in the

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knee and hip joints. Moreover, this feedforward control is characterized by supraspinal modulation and spinal circuit pre-conditioning (Dietz et al., 1992; Taube et al., 2008, 2012b; Yoshida et al., 2016). In particular, it has been shown that the regulation of intracortical inhibition controlling the agonist muscle affects DJ performance (Yoshida et al., 2016). Therefore, it can be understood that precise movement strategies are performed from the pre-set phase to the takeoff exertion in plyometric jumping tasks such as the DJ.

Visual feedback plays a fundamental role in regulating landing (Imai et al., 2025; Grooms et al., 2018; Terada et al., 2016) and running mechanics (Xia et al., 2025). Studies focusing on landing mechanics have shown that visual occlusion alters neuromuscular control strategies, leading to increased knee and hip flexion during landing as a compensatory adjustment (Imai et al., 2025; Grooms et al., 2018; Terada et al., 2016). Elite gymnasts employ rapid gaze stabilization to enhance performance, underscoring the importance of visual processing in complex jump executions (Sato et al., 2015). Moreover, individuals with visual impairment rely more on proprioceptive and vestibular cues, demonstrating altered muscle activation patterns and force distribution (Khadive et al., 2022; Magalhães and Goroso, 2011). Recent evidence also indicates that even the visual presence of a force plate can modify locomotor strategies, producing measurable changes in joint kinematics, ground reaction forces, and muscle activation during running (Xia et al., 2025). In this context, proprioceptive capacity, particularly ankle mobility and foot stability, has been shown to significantly influence jump performance and postural stability (Patti et al., 2024), suggesting that sensory adaptation mechanisms in plyometric tasks may depend on both central and peripheral proprioceptive integration.

DJs are widely used to assess the SSC abilities of the lower limbs, implement plyometric training, and support rehabilitation. Therefore, it is important to understand how visual input influences DJ execution in order to enhance performance, facilitate motor learning and support clinical applications. Recent studies have shown that attentional focus can lead to immediate improvements in DJ performance (Furuhashi et al., 2023), and watching instructional movies can lead to immediate improvements in DJ performance by affecting improvements in kinematics and kinetics, such as increased ankle joint torque and power output as well as decreased knee flexion (Yoshida et al., 2024). In this study, we evaluated DJ performance directly without visual input, which may deepen our understanding of the sensory-dependent mechanisms involved in DJ takeoff. These findings could benefit athletes with visual impairment or those training in environments with limited visual cues.

The present study investigated the acute effects of blocking visual information during the pre-set phase of the DJ, analyzing the DJ-index, jump height, contact time, along with lower limb kinematics and kinetics. Given the importance of neuromuscular control in plyometric execution, the study examined whether visual feedback would play a crucial role in modulating landing strategies and force production during the DJ. By elucidating the role of visual feedback in plyometric training, this research offers insights that may contribute to movement optimization strategies across diverse athletic populations.

Methods

Participants

Fourteen healthy male university track and field athletes (age: 22.0 ± 2.2 years; body height: 174.8 ± 2.4 cm; body mass: 70.3 ± 4.8 kg) participated in this study. A priori power analysis was conducted using G*Power (version 3.1) to evaluate the adequacy of the sample size for detecting within-participant differences in the DJ-index of the DJ. Assuming a type I error rate of 0.05 and an observed effect size of Cohen's $d = 0.80$ for the DJ-index, the calculated statistical power ($1-\beta$) was 0.79. This result suggests that the sample size (n = 14) was sufficient to detect large effects under the visual occlusion condition. To ensure participants' eligibility, participants were required to: have at least one year of experience in plyometric training, including regular exposure to drop jump exercises, be free of any neuromuscular disorders or lower limb injuries for at least six months prior to participation, and avoid any resistance training 24 h before testing.

Ethical approval was obtained from the ethics committee of the Faculty of Health and Sports Sciences, University of Tsukuba, Ibaraki, Japan (protocol code: tai 019-18; approval date: 14

November 2019). All participants provided written informed consent after being fully informed about the purpose, methods, and potential risks of the experiment. To ensure participant confidentiality, all collected data were securely encrypted, and researchers did not have access to any personally identifiable information during or after data collection.

Measures

Before testing, participants performed 15 min of low-intensity jogging and dynamic stretching as part of their standardized warm-up. To mitigate learning effects and technical variability, participants practiced DJ execution in advance (Bergmann et al., 2013). Following the warm-up, participants rested for 2 min before the trials to ensure standardization in physical readiness. Each participant completed two DJ trials from a 0.3 m platform under both normal (visual feedback) and blind (eye-mask occlusion) conditions. Ground reaction forces (GRFs) were recorded using two Kistler force plates (9287C; 0.9 m × 0.6 m; Kistler, Winterthur, Switzerland) at 1,000 Hz (Yoshida et al., 2024; Zushi et al., 2022), while three-dimensional marker coordinates were captured using a Vicon T20 system with 10 cameras (250 Hz). To measure ground reaction forces for each leg separately, participants were instructed to step onto the force plates using one leg at a time, allowing independent analysis of bilateral force production. Since participants were accustomed to performing jumps with arm swings, all trials were conducted without restrictions on arm movement, ensuring natural execution and minimizing variability in jumping technique.

Design and Procedures

The experimental design employed a repeated-measures approach, where each participant performed DJ trials under two conditions: normal (visual feedback available) and blind (visual feedback occluded). The independent variable was visual condition, while dependent variables included GRFs, joint kinematics and kinetics, as well as DJ performance measures.

In this study, the DJ was performed under two conditions: a blind condition, in which participants wore eye masks to block vision before performing the jump, and a normal condition, where participants executed the jump without visual restriction, following a signal from the assessor. The predefined order of jumps was consistent across participants to minimize order effects. The jumps from two trials per condition were statistically analyzed by calculating the mean values of performance variables (DJ-index, jump height, contact time), kinematic, and kinetic variables. To minimize fatigue effects, participants were given a 5-min rest interval between trials (Comyns et al., 2011). This rest interval was carefully controlled to ensure adequate recovery while preventing the immediate influence of prior trials. No feedback on performance was provided throughout the study to prevent adaptive modifications in execution.

The three-dimensional coordinates of 13 retro-reflective markers (diameter: 14 mm) fixed to the body were collected using a Vicon T20 motion analysis system with 10 cameras operating at 250 Hz. Auto-labeling was applied for marker tracking. During preliminary trials, potential swapping of left and right hip joint markers was identified; hence, a dummy marker was attached to one thigh to mitigate this issue. If swapping occurred, coordinates were interpolated to maintain accuracy. Markers were securely fixed using kinesiology tape (NITREAT Kinesiology Tape; Nitto Group, Osaka, Japan) to ensure stability throughout the measurement period (Yoshida et al., 2024).

GRFs were measured using two Kistler force plates (9287C; 0.9 m × 0.6 m; Kistler, Winterthur, Switzerland) at 1,000 Hz, and data were time-synchronized using Vicon Nexus software (Nexus 2; Vicon Motion Systems, Ltd., Los Angeles, CA, USA) for subsequent inverse dynamic analyses. The dominant leg was used for data analysis. Performance metrics including jump height, contact time, and the DJ-index were calculated based on vertical ground reaction forces, with jump height determined using the free-fall formula (Bosco et al., 1983; Taube et al., 2012b): jump height = $(g \cdot tair^2)\ 8^{-1}$, with “g” as the gravitational acceleration with a value of 9.81 m/s. The DJ-index was calculated as jump height divided by contact time (Yoshida et al., 2024; Zushi et al., 2022, 2023).

Joint torque and angle calculations were performed using a previously established coordinate system (Zushi et al., 2022) to ensure consistency. Twelve representative body points were tracked per participant, with a dummy marker used to validate hip joint tracking. The ankle, knee, and hip joints were analyzed for plantar flexion, dorsiflexion, extension, and flexion, following the structured joint movement coordinate system. The global coordinate system was defined using participants' jumping directions: X-axis (mediolateral direction), Y-axis (anterior-posterior direction), Z-axis (vertical direction). All kinematic data were processed using a fourth-order, zero-lag, low-pass Butterworth filter with optimal cutoff frequencies (7.5–15 Hz), determined via residual analysis (Wells and Winter, 1980). The center of mass estimations and inertial variables were based on the body segments of Japanese athletes (Ae et al., 1996).

GRFs and joint kinetics were divided into first half (eccentric) and second half (concentric) phases based on the lowest center of the gravity point during takeoff. Joint torque was computed using an inverse dynamics approach and transformed into a joint coordinate system. Joint power was calculated as the dot product of joint torque and angular velocity, with positive extension and negative flexion (plantar flexion/dorsiflexion) quantified across all lower limb joints. Negative and positive joint work values were calculated by integrating the power over time.

Statistical Analysis

Intraclass correlation coefficients (ICCs) were computed to assess measurement reliability. The Shapiro-Wilk test confirmed normality of data distribution, and all results are presented as mean ± standard deviation and confidence intervals.

Paired *t*-tests were conducted to compare performance metrics between conditions (normal vs. blind), with Cohen's *d* effect sizes calculated to assess practical significance (Cohen, 1992). Alpha was set at 0.05. SPSS version 25 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Reliability coefficients were generated within the authors' laboratory to validate the experimental protocol rather than relying on external sources.

Results

The DJ-index demonstrated high inter-measurement reliability under both conditions (ICC = 0.908 for the normal condition, ICC = 0.885 for the blind condition). The Shapiro-Wilk test confirmed that data were normally distributed (normal condition = 0.806, blind condition = 0.418).

Table 1 and Figure 1 show DJ performance variables. The DJ-index was significantly lower under the blind compared to the normal condition ($p < 0.001$, ES = 0.71), indicating reduced SSC efficiency due to visual occlusion. Contact time significantly increased ($p < 0.001$, ES = 0.90), whereas jump height showed no significant difference ($p = 0.27$, ES = 0.10).

Table 2 shows the flexion and extension angles of the lower limb joints. Hip flexion ($p = 0.014$, ES = 0.80) and knee flexion ($p = 0.028$, ES = 0.58) increased significantly under the blind condition. Knee extension was significantly greater under the blind condition compared to the normal condition ($p = 0.046$, ES = 0.44).

Table 3 shows the peak and mean GRFs. Peak GRF ($p = 0.011$, ES = 0.79), mean eccentric force ($p = 0.006$, ES = 0.89), and concentric force ($p = 0.006$, ES = 0.87) were significantly lower under the blind condition.

Table 4 shows torque, power, and work variables for the lower limb joints. Ankle eccentric and concentric torque ($p = 0.008$, ES = 0.50; $p = 0.005$, ES = 0.56), as well as negative and positive power ($p = 0.001$, ES = 0.51; $p = 0.005$, ES = 0.78) were significantly lower under the blind condition. Negative hip work increased significantly under the blind condition ($p = 0.003$, ES = 0.50).

Table 1. DJ-index, jump height, and contact time for each condition.

Variables	*Normal*		*Blind*		*95%CI*		*p-value*	*Effect size (Δ)*
	Mean	*SD*	*Mean*	*SD*	*lower limit*	*upper limit*		
DJ-index (m/s)	2.384	0.499	2.028	0.368	0.205	0.507	0.000**	0.71
Jump height (m)	0.443	0.088	0.435	0.086	−0.725	2.382	0.270	0.10
Contact time (s)	0.188	0.030	0.216	0.032	−0.039	−0.016	0.000**	0.90

** $p < 0.01$

Table 2. The flexion and extension of the three lower limb joints for each condition.

Variables	*Joint*	*Normal*		*Blind*		*95%CI*		*p-value*	*Effect size (Δ)*
		Mean	*SD*	*Mean*	*SD*	*lower limit*	*upper limit*		
Amount of joint flexion (°)	Hip	3.72	4.22	7.11	5.75	−5.97	−0.80	0.014*	0.80
	Knee	21.74	8.24	26.48	9.14	−8.88	−0.59	0.028*	0.58
	Ankle	23.98	7.41	24.29	7.20	−2.19	1.58	0.730	0.04
Amount of joint extension (°)	Hip	37.95	12.08	39.41	11.98	−5.36	2.43	0.431	0.12
	Knee	55.16	8.77	59.03	8.60	−7.67	−0.08	0.046*	0.44
	Ankle	55.46	6.34	55.19	6.37	−2.29	2.82	0.827	0.04

* $p < 0.05$

Table 3. The peak and mean ground reaction forces during the trials for each condition

Variables	*Phase*	*Normal*		*Blind*		*95%CI*		*p-value*	*Effect size (Δ)*
		Mean	*SD*	*Mean*	*SD*	*lower limit*	*upper limit*		
Peak ground reaction force (N/kg)		38.75	8.89	32.95	7.81	1.59	10.01	0.011*	0.79
Mean ground reaction force (N/kg)	Ecc.	22.58	4.69	18.69	2.82	1.35	6.42	0.006*	0.89
	Con.	16.87	2.04	15.42	1.92	0.49	2.40	0.006*	0.87

* $p < 0.05$; *Ecc.: Eccentric phase; Con.: Concentric Phase*

Table 4. The torque, power, and work data for the three lower limb joints under each condition.

Variables	*Phase*	*Joint*	*Normal*		*Blind*		*95%CI*		*p-value*	*Effect size (Δ)*
			Mean	*SD*	*Mean*	*SD*	*lower limit*	*upper limit*		
Mean joint torque (N/kg)	Ecc.	Hip	2.16	0.90	2.09	0.82	0.08	0.45	0.764	0.08
		Knee	1.96	0.24	2.01	0.42	−0.31	0.21	0.673	0.22
		Ankle	2.24	0.54	1.97	0.48	−0.41	0.55	0.008**	0.50
	Con.	Hip	1.08	0.37	1.12	0.42	0.08	0.37	0.687	0.10
		Knee	1.94	0.29	1.92	0.31	−0.10	0.13	0.774	0.06
		Ankle	2.17	0.40	1.95	0.35	−0.23	0.16	0.005**	0.56
Mean joint power (W/kg)	Negative	Hip	−7.81	5.18	−9.01	7.24	−5.03	−1.57	0.199	0.23
		Knee	−10.77	5.39	−9.67	4.01	−3.57	1.38	0.357	0.20
		Ankle	−11.07	6.52	−7.77	4.59	−0.71	3.08	0.001**	0.51
	Positive	Hip	4.05	2.31	3.98	2.28	0.69	3.20	0.880	0.04
		Knee	10.16	2.30	9.52	2.24	−0.34	1.62	0.180	0.28
		Ankle	12.43	2.52	10.48	2.06	−0.86	0.99	0.005**	0.78
Joint work (J/kg)	Negative	Hip	−0.29	0.23	−0.40	0.27	−0.20	−0.01	0.003**	0.50
		Knee	−0.67	0.27	−0.77	0.34	−0.05	0.24	0.190	0.35
		Ankle	−0.69	0.34	−0.58	0.24	0.05	0.18	0.028*	0.31
	Positive	Hip	0.52	0.38	0.58	0.35	0.04	0.19	0.390	−0.15
		Knee	0.92	0.29	0.93	0.31	−0.14	0.10	0.734	0.07
		Ankle	1.39	0.21	1.27	0.23	−0.19	0.08	0.007**	0.55

* $p < 0.05$; ** $p < 0.01$

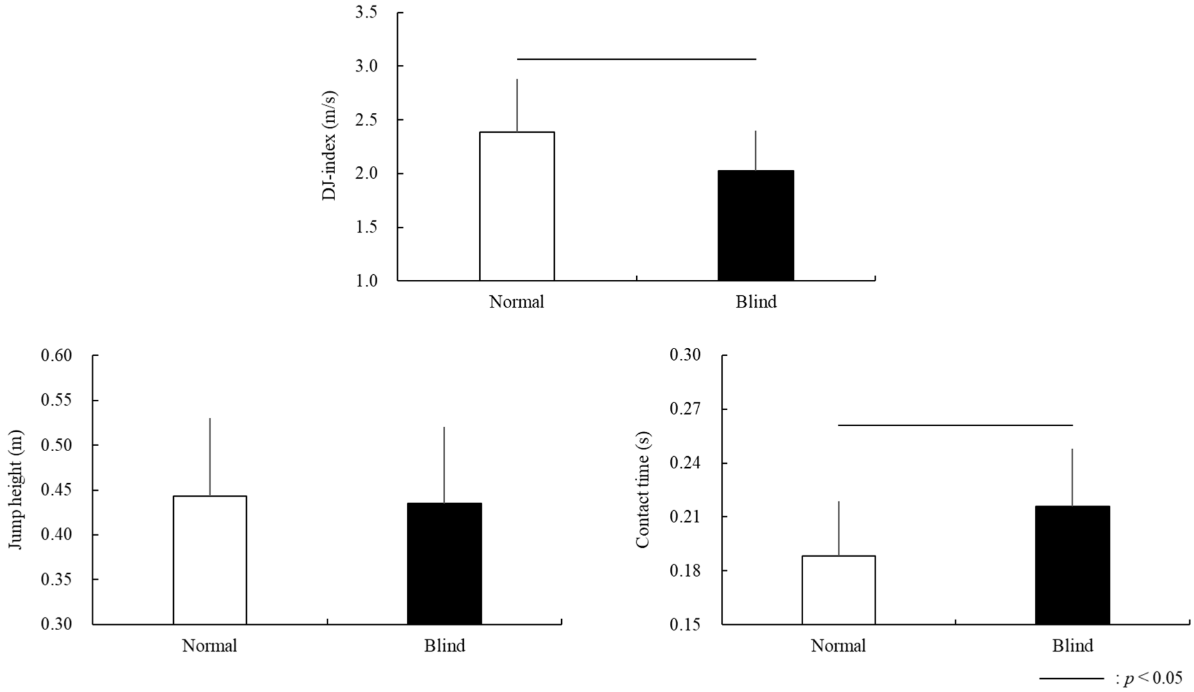

Figure 1. Comparison of the DJ-index, jump height, and contact time under each condition.

Discussion

The present study examined the effects of visual information blocking on the pre-set phase of DJ execution, focusing on the DJ-index, jump height, and contact time. Results indicated a significant decrease in the DJ-index and a notable increase in contact time under the blind condition, while jump height remained unchanged (Table 1). Previous research has reported that visual occlusion can both increase contact time and decrease jump height (Zushi and Takamatsu, 1995). However, the present findings suggest that contact time is more sensitive to visual restrictions than jump height, implying a stronger dependence on visual feedback for spatial and impact modulation strategies. This aligns with theories suggesting that jump height in explosive movements relies more on intrinsic neuromuscular coordination and stored elastic energy, whereas contact time is directly influenced by anticipatory mechanisms and landing control strategies (Dietz et al., 1992; Leukel et al., 2012; Taube et al., 2012; Zushi and Takamatsu, 1995). In addition to neuromuscular coordination and elastic energy utilization, recent findings suggest that joint mobility and postural control variables such as ankle stability, and the center of pressure behavior also play a critical role in vertical jump execution, particularly through anticipatory postural adjustments and landing stabilization (Patti et al., 2024). Therefore, it is thought that the lack of visual information made it difficult to form spatial and temporal strategies, which affected neuromuscular control and posture control during takeoff and increased contact time during landing. However, jump height remained unchanged, likely due to compensatory mechanisms such as increased knee joint extension and modified force production strategies during takeoff (Bobbert et al., 1987; Marshall et al., 2013). These findings suggest that while visual feedback refines SSC efficiency, explosive power can be maintained through biomechanical adjustments.

Additionally, the GRF results (Table 3) further highlight how visual occlusion influenced landing impact kinetics. Peak GRF values were significantly lower under the blind condition, suggesting a more controlled landing strategy with increased joint flexion (Grooms et al., 2018; Ko et al., 2022; Santello et al., 2001). This pattern resembles the kinetic characteristics of soft-landing styles, which are associated with longer contact times, reduced GRFs, and lower leg stiffness (You and Huang, 2022). This adaptation is likely associated with greater knee and hip flexion (Table 2), which can enhance shock absorption but may also reduce force transmission efficiency during propulsion. Furthermore, mean GRF values during the eccentric and concentric phases were significantly lower under visual occlusion, indicating reduced ground interaction forces that could affect SSC utilization and elastic energy storage. Given the central role of GRF in explosive movements, these reductions suggest that visual guidance contributes to optimizing force absorption and redistribution, reinforcing the necessity of spatial anticipation for efficient SSC function.

Interestingly, the present study results revealed increased hip and knee flexion under the blind condition, mirroring previous findings that demonstrated greater joint flexion during landing when visual input was restricted (Grooms et al., 2018; Ko et al., 2022; Santello et al., 2001). These adaptations may enhance shock absorption but potentially reduce force production efficiency, a critical factor in SSC utilization for plyometric movements. The kinetic responses further highlight that ankle torque, power, and work were significantly reduced under the blind condition (Table 4). Given the central role of the ankle joint in DJ takeoff (Bobbert et al., 1987; Kovács et al., 1999; Marshall et al., 2013), these reductions suggest that alternative sensory feedback mechanisms must be reinforced to compensate for the loss of visual guidance.

This study presents several limitations. First, the sample size was relatively small. A post hoc power analysis using G*Power (version 3.1) indicated that the statistical power (1−β) was 0.79 for an observed effect size of $d = 0.80$. This suggests that the current sample was sufficient to detect large effects; however, future research should involve a larger participants' pool to improve generalizability and allow detection of medium or small effects. Second, all participants were male athletes. Previous studies have suggested that takeoff mechanics during drop jumps may be influenced by sex-based differences. Therefore, future investigations should include more diverse populations (including competitive athletes such as volleyball or basketball players) to explore gender-specific adaptations in plyometric performance.

Conclusions

The present study demonstrated that visual information blocking significantly affected anticipatory landing control, leading to increased contact time and reduced GRFs, while jump height remained unchanged, likely due to compensatory mechanisms such as modified force production strategies. These findings highlight the critical role of visual feedback in optimizing SSC efficiency, particularly in force absorption and propulsion. The observed reductions in ankle torque and power suggest that training strategies focusing on proprioceptive and sensory adaptation could mitigate performance limitations associated with visual restrictions. These results emphasize the necessity of integrating sensory-adaptive strategies in plyometric training, including proprioceptive-based drills and sensory substitution technologies, to optimize movement execution for athletes with visual impairment or altered sensory reliance.

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Informed Consent: Informed consent was obtained from all participants included in the study.

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