SIN-CHN SCIENTIFIC PRESS PTE.LTD.

Molecular & Cellular Biomechanics 2024, 21(4), 290.
https://doi.org/10.62617/mcb290

Article

Moderate vision impairment to hip motion during vertical jumps: A pilot randomized cross-over study

Chengyuan Zhu[1], Xue Li[1], Julien S. Baker[2], Shirui Shao[1,3,*], Yaodong Gu[1,4]

[1] Faculty of Sports Science, Ningbo University, Ningbo 315211, China
[2] Centre for Health and Exercise Science Research, Hong Kong Baptist University, Hong Kong 999077, China
[3] Faculty of Engineering, University of Szeged, 6720 Szeged, Hungary
[4] Department of Radiology, Ningbo No. 2 Hospital, Ningbo 315010, China
*** Corresponding author:** Shirui Shao, shaoshirui@nbu.edu.cn

CITATION

Zhu C, Li X, Baker JS, et al. Moderate vision impairment to hip motion during vertical jumps: A pilot randomized cross-over study. Molecular & Cellular Biomechanics. 2024; 21(4): 290. https://doi.org/10.62617/mcb290

ARTICLE INFO

Received: 11 January 2024
Accepted: 13 August 2024
Available online: 25 December 2024

Abstract: Objective: To examine performance and lower limb kinematics between participants with clear and unclear vision when performing a specifical submaximal jump. Measures include success rate, jump accuracy, and joint angle. **Methods:** 12 males, aged 22.2 ± 1.2 years, with moderate vision impairment (left vision: 0.12 ± 0.02, right vision: 0.13 ± 0.04) and no professional athletic background were recruited in the randomized and cross-over designed trial according to the effect size and statistical power. After collecting the anthropometric data, each participant was asked to finish 2 tasks of a specifical submaximal jump to touch a static or moving target with or without vision correction in random order and with a 1-week interval rest. The success rate was recorded by the experimenter, and the jump accuracy, and joint angle data were captured by inertial motion capture (IMC). Statistical analysis included the X^2 test to analyze the success rates and the independent sample *T*-test to analyze jump accuracy and joint angle data. When data were not normally distributed the Mann-Whitney *U* test was used as a substitute. **Result:** The study found no significant differences in success rate or jumping accuracy between the group with moderate vision impairment and the group with normal vision. However, significant differences were observed in hip joint movements during both static and moving target tests. Hip minimum angles increased when participants wore optical correction and the target was static (Corrected: −6.07 (−9.61, −2.74), uncorrected: −4.52 (−7.46, −1.01); $Z = -2.66$, $p = 0.008$), but decreased in both hip minimum (Corrected: −5.14 (−9.31, 0.15), uncorrected: −7.08 (−10.92, −2.47); $Z = -2.72$, $p = 0.006$) and maximum (Corrected: 60.74 (48.67, 69.63), uncorrected: 56.27 (42.41, 65.05); $Z = -2.83$, $p = 0.004$) angles when the target was moving. **Conclusions:** No evidence was found to suggest that mild distance visual impairment on vertical jump success rate or vertical jumping accuracy including the horizontal plane and vertical axis. We found that mild distance visual impairment can affect hip joint movements during 75% vertical jumps whether the target is moving or static.

Keywords: myopia; athletic performance; countermovement jump; motor control; submaximal jump; lower extremity

1. Introduction

The vertical jump is a fundamental skill used in various sports. Athletes often aim for a specific vertical jump height that is often sub-maximum [1]. Jumping to a necessary height can save athletes time and energy over the game's duration. While few studies have investigated jumping accuracy at a specific percentage height [1].

Visual information can play a significant role in sports. Research has reported that maximum running speed can relate to mammalian eye size [2]. Numerous studies have shown that humans' ability to maintain posture and balance relies heavily on environmental information from the visual system [3–6]. In addition, vision can provide information about temporary situations on the court, such as the ball's height and speed [7] (p. 5). Visual training has proven to be an effective way to enhance exercise performance [8]. Therefore, visual impairment can be a negative factor that impacts players' performance in competitions.

Myopia is a very common condition in several countries in East and Southeastern Asia [9]. One study has reported a high prevalence of myopia (50.18%) among young sports-related groups in China [10]. The association between college students' physical performance and visual acuity (VA) has also been reported in China [11]. According to this research, poor VA can be associated with lower physical performance. Although distance vision impairment is usually considered a negative factor for exercise performance [12], research has also suggested that in some sports, such as judo, VA only significantly decreases sports performance after reaching a limit line [13]. Notably, many high-degree athletes have distance impairments and do not use optical correction in competition [13]. The results of these studies appear to be conflicting. Therefore, given the myopia epidemic in East and Southeast Asia and the contradictory studies, this present research aims to determine the correlation between distance vision impairment and vertical jump accuracy.

To execute a vertical jump accurately, the visual system must perceive information about the target, and the neuromuscular system must adjust accordingly to adapt to the intended jump height, resulting in changes in kinematics [14]. However, there are inconsistent reports about which factors control jump height. Some studies suggest that knee joint flexion angle is a crucial control factor [15], while others suggest that the flexion amplitude of the hip joint increases with jump height, while ankle and knee joint flexion does not [16]. Therefore, differences in vision may result in changes in lower limb kinematics.

Neither of the two studies mentioned above has investigated vertical jump performance using arm swings, which are more commonly used in competitions [17]. On unstable surfaces like sand, significant effects of arm swing were observed on jump height, maximum power output, temporal parameters, range of motion, and angular velocity of the hip [18]. As mentioned previously, myopia can affect balance. Therefore, differences in jump height control strategies between those with myopia and those without may be observed in lower limbs kinematics and provide further interpretations for previous findings.

Therefore, the objective of this study was to examine the discrepancies in success rate related to touching a specific height target, vertical jump accuracy in horizontal plane error and height, and lower limb kinematics between participants with clear and unclear vision while performing a sub-maximum vertical jump with arm swing to a specified height. The hypothesis of this study posits that impaired vision may negatively influence the success rate, jumping accuracy, and lower limb kinematics during the execution of a sub-maximal vertical jump with arm swing to a specified height. This investigation holds significance for sports selection and training strategies tailored to myopic athletes.

2. Materials and methods

2.1. Participants recruitment and ethics

The participants were recruited from the Faculty of Sports Science, Ningbo University. The information was published online by one of the researchers, and the volunteers registered their information. Another researcher included and excluded volunteers according to the criteria for the trial. Volunteers did not receive any information about the experimental process and purpose in this period.

The inclusion criteria of participants were: (1) 18–26 years; (2) with moderate vision impairment; (3) No professional athletic background; (4) had no history of lower limb injuries in the past 12 months or medical or orthopaedic disorders of balance or postural control. The exclusion criteria of participants were as follows: (1) under 18 years old or over 26 years old; (2) have no moderate vision impairment; (3) have a professional athletic background; (4) suffered lower limb injuries in the past 12 months, or have medical or orthopaedic disorders of balance or postural control; (5) with endocrine, metabolic, neuromuscular, or musculoskeletal disorders or be clinically required avoid any physical exercise; (6) be asked to participate in the trial involuntarily. Visual acuity was measured using the logarithm of the minimum angle of resolution (logMAR) chart, which is commonly used [19], and in this test, we used the Standard for Logarithmic Visual Acuity Charts, GB 11533-2011 of the Standardization Administration of the People's Republic of China. Participants were considered to have moderate vision impairment if their visual acuity was worse or equal to 0.3 and better or equal to 0.1, and their corrected visual acuity (CVA) was not worse than 1.0, which is considered normal vision according to the World Health Organization's criterion [7] (p. 11). The examination measuring both VA and CVA was performed under no direct sunlight and shadows.

All participants provided written informed consent, and the study was approved by the Institutional Ethics Committee of Ningbo University (TY2023020).

2.2. Experimental procedure

The trial was randomized and cross-over controlled. Each participant was asked to finish 2 sessions of tasks. Volunteers were asked to finish a sub-maximum vertical jump with arm swing to touch a specified height target in the daytime (from 8:00 to 17:00). One task requirement was finishing with corrected vision first and uncorrected vision before and the other task was in the opposite sequence. The tasks that participants were required to complete when they first participated in the experiment were randomized, and the IBM SPSS Statistics (version 27, SPSS AG, Zurich, Switzerland) was used for the allocation of the participants. In both tasks, the participants were asked to be barefoot. To eliminate the interference of the learning effect, each group exchanged their optical correction sequence and were retested after a week. Blinding was not possible in this trial.

Participants were asked to refrain from caffeine intake and training for 48 h before the tests. All provided signed informed consent forms, and all were fully familiarized with experimental procedures prior to data collection. Before the vertical jump tasks, each participant completed a 10-minute warm-up and practice session.

Next, participants were outfitted with the Xsens MTw Awinda motion capture system (Xsens Technologies B.V., the Netherlands), and their height from foot to fingertip when reaching up as far as possible with two hands h_1 was measured. Three maximum height countermovement jumps (CMJs) with arm swing were performed by each participant to determine their maximum vertical jump ability, and the height data, as well as the body's centre of mass (COM) height h_{com}, were captured by the Xsens system. In these three trial jumps, the maximum jumping height of the participants is defined as the difference between the h_{com} at the highest point during the jump and the h_{com} when standing $h_{\max}$. Following the maximum jump height tests, a target ball was positioned at a specific height based on the previously measured $h_{\max}$ using the Equation (1) and hung using a bundling rope due to its low elasticity and high strength, which minimizes error in h_{target} measurement. The test site was set up with a black cross underneath the target ball, which served as the projection point of the target on the ground and aided participants in positioning themselves correctly. Before each test, the experimenter ensured that the participant was standing straight beneath the target and facing the correct direction, as shown in **Figure 1**.

$$h_{\text{target}} = h_1 + 75\% h_{\max} \tag{1}$$

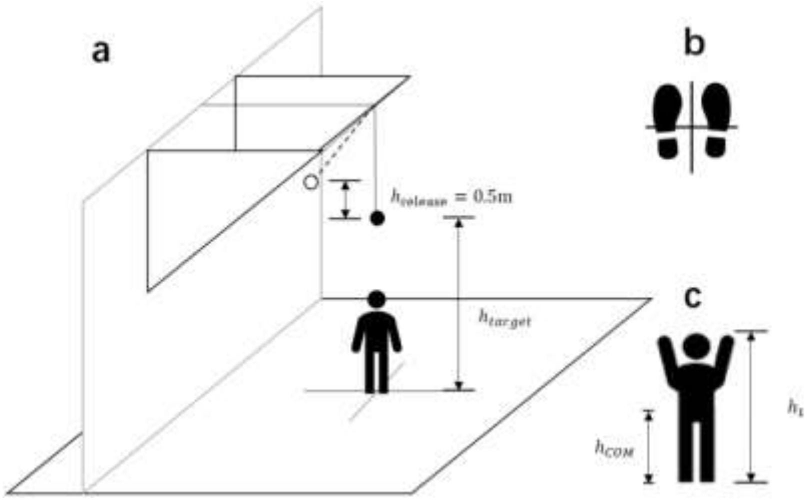

Figure 1. Experimental setup for vertical jump tasks. **(a)** The h_{target} is measured by Equation (1), with the release height h_{release} set 0.5 m above the target height. Participants face the target when it's moving and keep the same direction when it's static; **(b)** the test site includes a black cross under the target ball, marking its ground projection and helping participants with positioning; **(c)** the h_1 is measured as the distance from foot to fingertip when participants reach up with both hands. The COM is set at the pelvis.

Following a 3-minute break, participants were instructed to touch the target in the most efficient manner possible, which required participants to jump straight up and down and touch the bottom of the target with their fingertips. Each participant was required to complete 2 sets of tests with a static target and 2 sets with a moving target, with each set comprising 2 successful trials. If a mistake occurred during a jump, it was repeated, and the error was recorded. After each set of tests, the subjects were asked if they were tired, and if they were, they were given sufficient rest to continue the experiment. In the moving target tests, the target ball was released at the same altitude, and the bundling rope was straightened to ensure a similar speed for the moving target. The release height in this test was set to 0.5 m higher than the target height. The overall experimental procedure is illustrated in **Figure 2**.

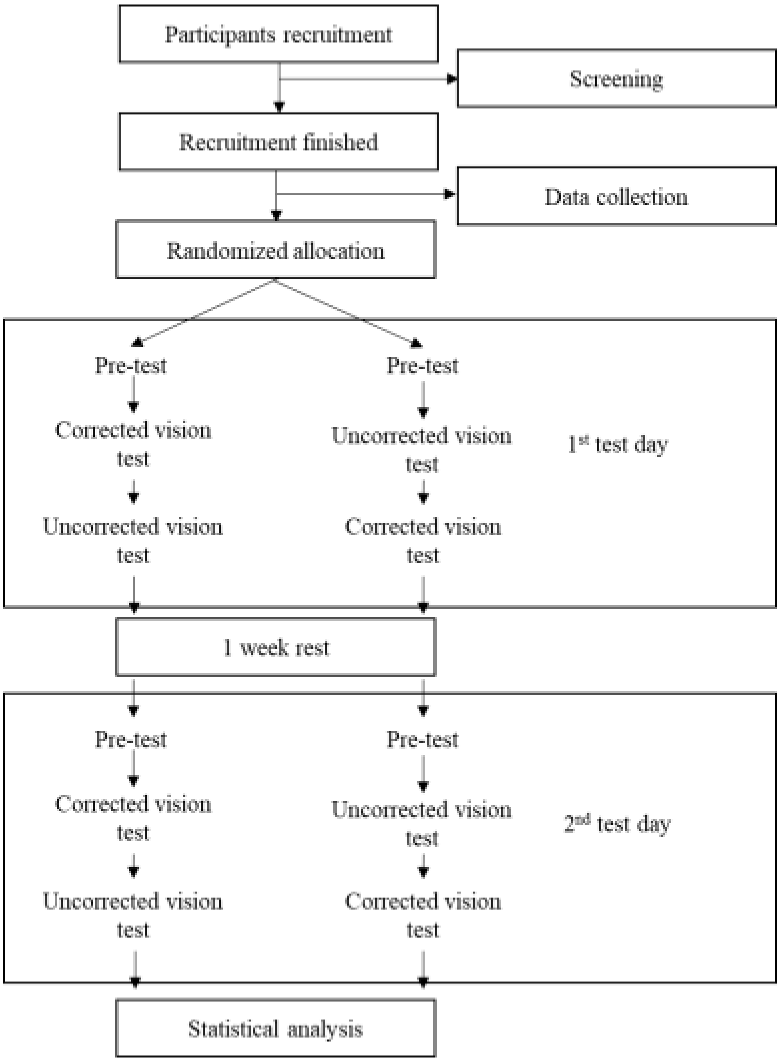

Figure 2. The schematic diagram of the trial.

The target speed was determined using Equations (2), where $v_{\max}$ represents the target's maximum speed and g is the acceleration due to gravity, which is taken as 9.8 m/s for this experiment. In this study, the target was released from a height difference of 0.5 m, resulting in a target speed of approximately 3.13 m/s. The target's height was measured before the start of each test group to ensure consistency throughout the experiment.

$$v_{\max} = \sqrt{2gh_{\text{release}}} \tag{2}$$

2.3. Data collection

The success rate was recorded by the experimenter during the trial, set to the number of failures as a percentage of the total number of attempts.

The kinematic data, including joint angles, were collected by the Xsens system and analyzed using Xsens MVN 2022.0.2 (Xsens Technologies B.V., the

Netherlands). The accuracy of the device has been supported by previous studies [20,21]. Additionally, this system was used to measure the COM's movement along the x-axis and y-axis during the jumping task.

The design equations for jump vertical accuracy were based on Struzik et al.'s methods [22] and were calculated using Equation (3), which provides accuracy measures as a percentage and error. The jump vertical accuracy (JVA) was based on the mean value of each group's successful trials for each percentage value $D_{75\%,z}$, and the error score was calculated as a percentage. The best vertical accuracy result is 0, and a higher value indicates lower accuracy. The Xsens system collected the jump horizontal plane accuracy (JHA) data as the COM's x-axis $D_{75\%,x}$ and y-axis $D_{75\%,y}$ movements during jumping. The best horizontal plane accuracy result is 0, and a higher value indicates lower accuracy.

$$D_{75\%,z} = \frac{|0.75 \cdot h_{\max} - h_i|}{0.75 \cdot h_{\max}} \times 100\% \tag{3}$$

2.4. Statistical analysis

The success rates of different vision corrections were compared using the X^2 test. If $n < 40$ or at least one $T < 1$, Fisher's exact test was used. Independent t-tests were used to compare the jumping accuracy and kinematics of different vision corrections. Normality was verified using the Kolmogorov-Smirnov (K-S) test. If normality was violated, the median and interquartile range were calculated instead, and the Mann-Whitney U test was used. All statistical analyses were performed using IBM SPSS Statistics (version 27, SPSS AG, Zurich, Switzerland). Significance was set at $p < 0.05$.

3. Results

A total of 12 subjects were eventually recruited for the experiment. **Table 1** summarizes the demographic information related to the age, height, weight, VA, and CVA of the participants.

Table 1. Information of the eligible participants.

Variable	Participants
Number	12
Age (years)	22.2 ± 1.2
Height (m)	1.78 ± 0.05
Weight (kg)	75.2 ± 4.2
VA(L)	0.12 ± 0.02
VA(R)	0.13 ± 0.04
CVA(L)	1.03 ± 0.02
CVA(R)	1.01 ± 0.01

Means ± SD or number as indicated. VA = vision accuracy. CVA = corrected vision accuracy. Participants' height, weight, VA and CVA tests were performed uniformly before the experiment.

3.1. Success rate

Table 2 shows that when the target was static, participants with clear vision achieved a success rate of 94.5% with an error rate of 5.5%, while participants with unclear vision had a success rate of 98.4% with an error rate of 1.6%. When the target started to move, both circumstances exhibited success rates of 69.0% and 71.9%, with error rates of 31.0% and 28.1%, respectively. There were no significant differences observed between the two groups in any other instances, regardless of whether the target was moving or static.

Table 2. Jump success rate.

Target condition	Groups	Success (%)	Error (%)	X^2	*p*
Static	Corrected	94.5	5.5	1.682	0.195
	Uncorrected	98.4	1.6		
Moving	Corrected	69.0	31.0	0.342	0.559
	Uncorrected	71.9	28.1		

n = Number of attempts; Success = Percentage of successful attempts; Error = Proportion of failed attempts. There were no significant differences observed between the two groups in any other instances, regardless of whether the target was moving or static.

3.2. Jumping accuracy

In this test, the vertical jumping accuracy data didn't pass the normality test, so the Mann-Whitney *U* test was used when comparing the jumping accuracy and the kinematics data.

As shown in **Table 3** and **Figure 3**, there were no significant differences between different vision conditions in $D_{75\%,x}$, $D_{75\%,y}$, and $D_{75\%,z}$ whenever the target is moving or static.

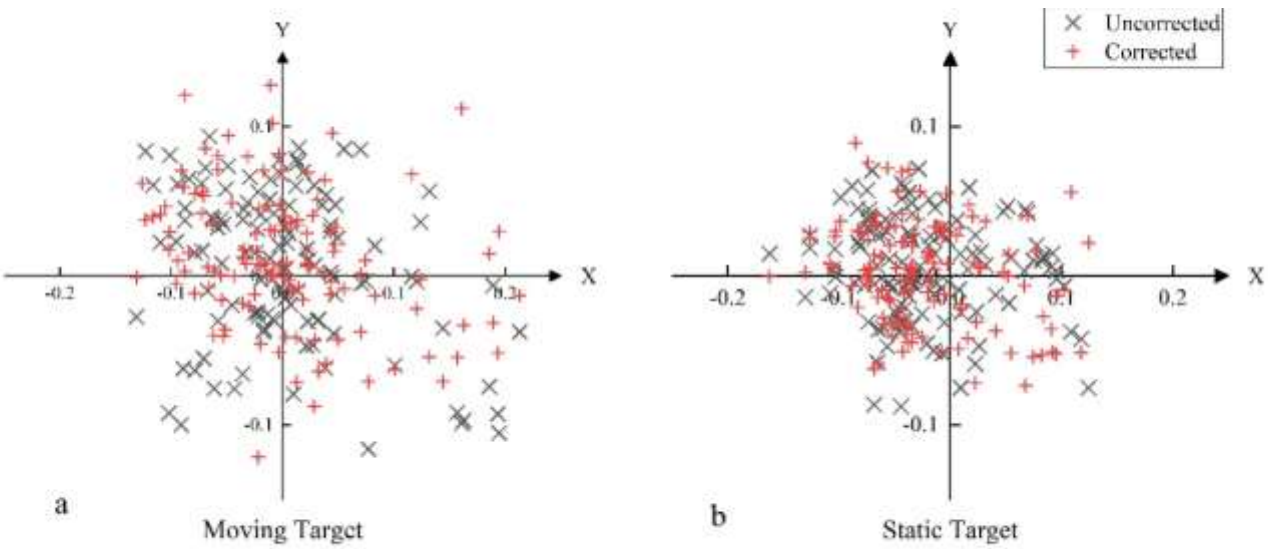

Figure 3. Horizontal plane drop points across Trials. **(a)** The horizontal plane drop point in moving target trial; **(b)** horizontal plane drop point in static target trial.

Figure 3 shows the horizontal plane drop point for each trial. The *X*-axis means the movement of the body from the left side to the right side. *Y* axis means the movement of the body from the anterior side to the posterior side. No significant difference can be observed between the corrected and uncorrected groups when the target is moving or static.

Table 3. Jumping accuracy.

Target condition	**Groups**	$D_{75\%,x}$, ***M*** **(P25, P75)**	**Mann-Whitney *U* test**	
			Z	***p***
Static	Corrected	−0.03 (−0.06, 0.01)	−1.118	0.265
	Uncorrected	−0.02 (−0.05, 0.02)		
Moving	Corrected	−0.00 (−0.05, 0.04)	−0.970	0.333
	Uncorrected	−0.02 (−0.07, 0.04)		
Target condition	**Groups**	$D_{75\%,y}$, **M (P25, P75)**	***Z***	***p***
Static	Corrected	0.00 (−0.02, 0.03)	−1.008	0.315
	Uncorrected	0.01 (−0.01, 0.03)		
Moving	Corrected	0.01 (−0.01, 0.04)	−0.290	0.773
	Uncorrected	0.01 (−0.03, 0.05)		
Target condition	**Groups**	$D_{75\%,z}$, **M (P25, P75)**	***Z***	***p***
Static	Corrected	12.03% (9.51%, 15.61%)	−0.184	0.855
	Uncorrected	12.48% (10.07%, 15.43%)		
Moving	Corrected	14.90% (11.32%, 19.44%)	−1.501	0.134
	Uncorrected	13.11% (9.08%, 18.18%)		

M (*P*25, *P*75) = median (upper quartile, lower quartile). No significant difference can be observed between the corrected and uncorrected groups when the target is moving or static.

3.3. Kinematics

Throughout the test, we gathered data on the angles of the hip, knee, and ankle joints during each stage of a vertical jump, including standing, take-off, flight, and landing. Specifically, we recorded the flexion and extension angles of these joints. In the case of the ankle joint, we recorded dorsiflexion as a positive number and plantarflexion as a negative number.

In this test, the angles of hip, knee, and ankle joints' flexion and extension angles data didn't pass the normality test, so the Mann-Whitney *U* test was used when comparing the jumping accuracy and the kinematics data.

As presented in **Table 4**, we observed a significant difference in hip minimum flexion angle ($Z = -2.66$, $p = 0.008$) between the corrected and uncorrected groups when the target was static. Throughout all stages of the vertical jump, the corrected group exhibited lower hip minimum angles. However, we did not observe any significant differences between the two groups regarding other joint flexion minimum angles, maximum angles, and range of motion.

Table 4. Joint movement during the whole stage of a vertical jump.

Condition	**Index**		**Corrected vs. uncorrected, *M* (*P*25, *P*75)**		**Mann-Whitney *U* test**	
					Z	***p***
Static	Hip	MAX (◦)	62.56 (54.46, 73.17)	65.38 (55.10, 75.13)	−0.774	0.440
		MIN (◦)	−6.07 (−9.61, −2.74)	−4.52 (−7.46, −1.01)	−2.665	0.008
		ROM (◦)	68.91 (58.61, 78.01)	69.32 (58.34, 81.08)	−0.320	0.750
	Knee	MAX (◦)	86.09 (77.66, 92.60)	86.58 (78.47, 91.61)	−0.086	0.933
		MIN (◦)	0.09 (−1.94, 1.95)	0.03 (−1.75, 0.85)	−1.179	0.239
		ROM (◦)	84.63 (78.43, 92.19)	86.21 (79.75, 91.20)	−0.668	0.506
	Ankle	MAX (◦)	35.09 (31.15, 39.81)	34.38 (30.82, 40.20)	−0.119	0.906
		MIN (◦)	−43.59 (−47.95, −35.76)	−42.88 (−47.68, −36.57)	−0.240	0.811
		ROM (◦)	79.82 (71.39, 84.74)	79.42 (69.46, 84.47)	−0.188	0.852
Moving	Hip	MAX (◦)	60.74 (48.67, 69.63)	56.27 (42.41, 65.05)	−2.834	0.004
		MIN (◦)	−5.14 (−9.31, 0.15)	−7.08 (−10.92, −2.47)	−2.717	0.006
		ROM (◦)	64.58 (53.46, 72.31)	62.34 (51.60, 70.62)	−1.337	0.182
	Knee	MAX (◦)	77.29 (71.23, 88.99)	78.06 (69.93, 89.63)	−0.704	0.483
		MIN (◦)	−0.20 (−2.24, 1.76)	−0.39 (−2.62, 1.64)	−0.812	0.418
		ROM (◦)	76.69 (71.68,88.13)	78.22 (69.42, 89.30)	−0.565	0.573
	Ankle	MAX (◦)	33.73 (30.80,36.90)	33.33 (30.64, 36.18)	−0.316	0.753
		MIN (◦)	−45.69 (−51.34, −39.38)	−45.39 (−50.14, −39.42)	−1.032	0.303
		ROM (◦)	81.26 (73.67, 87.22)	80.41 (73.87, 86.08)	−1.213	0.226

When the target was moving, we observed significant differences between the corrected and uncorrected groups in hip maximum angle ($Z = -2.83$, $p = 0.004$) and hip minimum angle ($Z = -2.72$, $p = 0.006$). The corrected group exhibited higher hip maximum and minimum angles than the uncorrected group, but we did not observe any significant differences in other joint movements between the two groups.

In summary, our results showed no significant differences in success rate and jumping accuracy between the group with moderate vision impairment and the group with normal vision. However, we did observe significant differences in hip joint movements during both static and moving target tests. Specifically, the corrected group exhibited increased hip minimum angles when the target was static, while both hip minimum and maximum angles decreased when the target was moving.

M (*P*25, *P*75) = median (upper quartile, lower quartile). We can observe significant differences in hip joint movements during both static and moving target tests. Specifically, the corrected group exhibited increased hip minimum angles when the target was static ($Z = -2.66$, $p = 0.008$), while both hip minimum ($Z = -2.72$, $p = 0.006$) and maximum angles ($Z = -2.83$, $p = 0.004$) decreased when the target was moving.

4. Discussion

In this study, we examined differences in vertical jump success rate, JVA, JHA, and the kinematics of lower limbs between clear and unclear vision when participants performed a specific height sub-maximum countermovement vertical jump with arm swing.

According to the results above, insignificant differences were revealed between moderate vision impairment and normal vision in vertical jump success rate, JVA, and JHA whether trying to touch a moving or static target. However, significant differences were observed in the kinematics field, especially in the hip joint. When the target is static, the uncorrected group's hip minimum angle decreased compared to the corrected group. Meanwhile, when participants need to complete a more difficult objective in which they need to touch a moving target in a very short time, significant differences appear in the hip joint's maximum angle and minimum angle. Both angles decrease with an insignificant change in hip range of motion.

The change in the visual system did not influence the success rate and jump accuracy. One possible reason might be that moderate vision impairment does not affect the success rate and jump accuracy when performing a 75% maximum high jump. This means that during this test we did not reach the limit line of VA below which the vertical jump accuracy can be significantly affected. The vertical jump used to touch a moving or static target may not be affected by low levels of visual blur and may be able to successfully compete with below-normal habitual vision [23]. We did not observe a significant difference in fixed height vertical jump because participants can maintain their performance under mild blur [24]. This may be attributed to the human body's remarkable adaptability, and in the absence of visual information, other sensory systems may intensify their functions to compensate for the deficiency like the proprioception [25,26]. We may need to design a harder vertical jump task such as increasing target speed or decreasing participants' reaction time that may cause more obvious differences when comparing normal vision and near-sightedness vision. This is a direction for our continued research.

However, the significant difference in hip joint movement may reveal vision system information changes affect the human motor control system. This change may cause a nearly unbalanced state in humans that affects a person to produce an adaptive change in the hip joint. Unlike the vertical jump test on soft places like sand [18]. To perform a high-quality vertical jump on the sand, athletes need to perform a higher range of motion on the hip joint to overcome the energy loss caused by soft surfaces and reach a greater height. In this task, due to the fixed height according to the participant's ability, the hip range of motion did not demonstrate a significant change when comparing the status of different visions. So, the change in the hip maximum angle joint and minimum angle joint may be an expression of human balance control when clear vision information is disrupted.

As described earlier, when the target is static hip minimum angle increased when subjects were uncorrected. Touching a static target is a simple task that does not need a clearer vision especially since the height is sub-maximum, so the hip did not change massively. When the target starts moving, we find that it's difficult for people to complete the task who have not been specially trained previously based on decreased success rate compared with the static target. In the meantime, the hip maximum angle and hip minimum angle both decreased, and we can observe that the hip movement is closer to the direction of gravity so this change may enhance body balance control to avoid tumble and avert accidental injury.

The mechanism behind this change appearing in the hip joint may be the need for the body to maintain balance under blurred visual information. When using the same level of force, the hip will produce a larger moment. Affected by this factor, a small angle change on the hip can be a considerable alteration in lower limbs and COM's relative location. This has a huge effect on the force pattern of the lower limbs. The change in hip movement can be an adjustment to maintain balance during a vertical jump. This change can make the hip joint's movement closer to gravity direction. Hip strengthening can be an important reason for improving balance ability [27,28], so we can imagine that changing hip kinematics without changing the hip strength can be an expression of an adaptive change of the hip.

In summary, no evidence was found to suggest that mild distance visual impairment on vertical jump success rate or vertical jumping accuracy including the horizontal plane and vertical axis. However, we found mild distance visual impairment can affect hip joint movements during 75% vertical jumps whenever the target is moving or static.

5. Limitations and future recommendations

Limitations of this test include that we did not analyse the movement of the upper limbs during all stages of the vertical jump with arm swing. We also only recruited male participants for this experiment, Due to differences in anatomy, females may exhibit different kinematics in the trial. Although we did mention the change of the hip above is an outward expression, the underlying mechanism such as muscle activation has not been investigated. In future studies, we will continue to explore the relationship between limb movement and vision. This will be a future direction of our continued research.

Author contributions: Conceptualization, CZ, SS and YG; methodology, CZ, XL and YG; software, CZ, SS and YG; validation, CZ and XL; formal analysis, CZ; investigation, JSB and YG; resources, JSB and YG; data curation, SS and XL; writing—original draft preparation, C.Z. and XL; writing—review and editing, JSB, SS and YG; visualization, CZ; supervision, YG; project administration, YG; funding acquisition, YG. All authors have read and agreed to the published version of the manuscript.

Funding: This study was sponsored by the Zhejiang Provincial Natural Science Foundation of China for Distinguished Young Scholars (LR22A020002), Zhejiang Provincial Key Research and Development Program of China (2021C03130), Zhejiang Provincial Natural Science Foundation (LTGY23H040003), Ningbo key R&D Program (2022Z196), Research Academy of Medicine Combining Sports, Ningbo (No.2023001), the Project of NINGBO Leading Medical &Health Discipline (No.2022-F15, No.2022-F22), Ningbo Natural Science Foundation (20221JCGY010532, 20221JCGY010607), Public Welfare Science & Technology Project of Ningbo, China (2021S134), Zhejiang Rehabilitation Medical Association Scientific Research Special Fund (ZKKY2023001).

Ethical approval: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Ethics Committee of Ningbo University (Protocol code: TY2023020. Date: 14 March 2023). Informed consent was obtained from all subjects involved in the study.

Availability of data and materials: The data supporting the findings of this study can be obtained upon reasonable request from the corresponding author. However, please note that the data are not publicly available due to privacy and ethical considerations.

Conflict of interest: The authors declare no conflict of interest.

References

1. Struzik A, Pietraszewski B, Kawczyński A, et al. Manifestations of Proprioception During Vertical Jumps to Specific Heights. Journal of Strength and Conditioning Research. 2017; 31(6): 1694-1701. doi: 10.1519/jsc.0000000000001868
2. Heard-Booth AN, Kirk EC. The Influence of Maximum Running Speed on Eye Size: A Test of Leuckart's Law in Mammals. The Anatomical Record. 2012; 295(6): 1053-1062. doi: 10.1002/ar.22480
3. Peterka RJ. Sensory integration for human balance control. Handbook of clinical neurology. 2018; 159: 27-42. doi: 10.1016/b978-0-444-63916-5.00002-1
4. Carini F, Mazzola M, Fici C, et al. Posture and posturology, anatomical and physiological profiles: overview and current state of art. Acta Bio Medica. 2017; 88: 11-16. doi:10.23750/abm.v88i1.5309
5. Mani H, Kato N, Hasegawa N, et al. Visual feedback in the lower visual field affects postural control during static standing. Gait & Posture. 2022; 97: 1-7. doi: 10.1016/j.gaitpost.2022.07.004
6. Xie M, Niehorster DC, Lappe M, et al. Roles of visual and non-visual information in the perception of scene-relative object motion during walking. Journal of Vision. 2020; 20(10): 15. doi: 10.1167/jov.20.10.15
7. World Health Organization. World report on vision. World Health Organization; 2019.
8. Knudson D, Kluka DA. The Impact of Vision and Vision Training on Sport Performance. Journal of Physical Education, Recreation & Dance. 1997; 68(4): 17-24. doi: 10.1080/07303084.1997.10604922
9. Morgan IG, Wu PC, Ostrin LA, et al. IMI Risk Factors for Myopia. Investigative Opthalmology & Visual Science. 2021; 62(5): 3. doi: 10.1167/iovs.62.5.3
10. Zhang M, Sun Z, Zhu X, et al. Sports and Myopia: An Investigation on the Prevalence and Risk Factors of Myopia in Young Sports-Related Groups in Tianjin, China. Investigative Opthalmology & Visual Science. 2022; 63(6): 27. doi: 10.1167/iovs.63.6.27
11. Wu K, Yang L, Sun X, et al. Physical performance is associated with visual acuity in university students: results of a school-based study. Revista da Associação Médica Brasileira. 2020; 66(3): 296-299. doi: 10.1590/1806-9282.66.3.296
12. Kimyon B, Ince G. The Comparison of Physical Fitness, Anthropometric Characteristics, and Visual Acuity of Goalball Players with Their Right Shot Performance. Journal of Visual Impairment & Blindness. 2020; 114(6): 516-530. doi: 10.1177/0145482x20972501
13. Krabben K, Mann DL, van Helden A, et al. Getting a grip on the resilience to blur: The impact of simulated vision loss on a visually guided combat sports interaction. Psychology of Sport and Exercise. 2021; 55: 101941. doi: 10.1016/j.psychsport.2021.101941
14. Van Zandwijk JP, Bobbert MF, Munneke M, et al. Control of maximal and submaximal vertical jumps. Medicine & Science in Sports & Exercise. 2000; 32(2): 477. doi: 10.1097/00005768-200002000-00033
15. Kai S, Nakahara M, Watari K, et al. Knee Joint Angle at the Time of Adjustment to Submaximal Jumping in Healthy Men. Journal of Physical Therapy Science. 2006; 18(1): 11-13. doi: 10.1589/jpts.18.11
16. Vanrenterghem J, Lees A, Lenoir M, et al. Performing the vertical jump: Movement adaptations for submaximal jumping. Human Movement Science. 2004; 22(6): 713-727. doi: 10.1016/j.humov.2003.11.001
17. Hara M, Shibayama A, Takeshita D, et al. A comparison of the mechanical effect of arm swing and countermovement on the lower extremities in vertical jumping. Human Movement Science. 2008; 27(4): 636-648. doi: 10.1016/j.humov.2008.04.001
18. Giatsis G, Panoutsakopoulos V, Kollias IA. Biomechanical differences of arm swing countermovement jumps on sand and rigid surface performed by elite beach volleyball players. Journal of Sports Sciences. 2017; 36(9): 997-1008. doi: 10.1080/02640414.2017.1348614
19. McMonnies CW. The Dependency of LogMAR Visual Acuity Measurements on Chart Design and Scoring Rule. Optometry and Vision Science. 2003; 80(7): 486. doi: 10.1097/00006324-200307000-00007

20. Dinu D, Fayolas M, Jacquet M, et al. Accuracy of Postural Human-motion Tracking Using Miniature Inertial Sensors. Procedia Engineering. 2016; 147: 655-658. doi: 10.1016/j.proeng.2016.06.266
21. Toft Nielsen E, Jørgensen PB, Mechlenburg I, et al. Validation of an inertial measurement unit to determine countermovement jump height. Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology. 2019; 16: 8-13. doi: 10.1016/j.asmart.2018.09.002
22. Struzik A, Rokita A, Pietraszewski B, et al. Accuracy of replicating static torque and its effect on shooting accuracy in young basketball players. Human Movement. 2018; 15(4): 216-220. doi: 10.1515/humo-2015-0014
23. Mann DL, Abernethy B, Farrow D. The resilience of natural interceptive actions to refractive blur. Human Movement Science. 2010; 29(3): 386-400. doi: 10.1016/j.humov.2010.02.007
24. Mann DL, Ravensbergen HJC. International Paralympic Committee (IPC) and International Blind Sports Federation (IBSA) Joint Position Stand on the Sport-Specific Classification of Athletes with Vision Impairment. Sports Medicine. 2018; 48(9): 2011-2023. doi: 10.1007/s40279-018-0949-6
25. Proske U, Gandevia SC. The Proprioceptive Senses: Their Roles in Signaling Body Shape, Body Position and Movement, and Muscle Force. Physiological Reviews. 2012; 92(4): 1651-1697. doi: 10.1152/physrev.00048.2011
26. Bellan V, Gilpin HR, Stanton TR, et al. Untangling visual and proprioceptive contributions to hand localisation over time. Experimental Brain Research. 2015; 233(6): 1689-1701. doi: 10.1007/s00221-015-4242-8
27. Jeong UC, Sim JH, Kim CY, et al. The effects of gluteus muscle strengthening exercise and lumbar stabilization exercise on lumbar muscle strength and balance in chronic low back pain patients. Journal of Physical Therapy Science. 2015; 27(12): 3813-3816. doi: 10.1589/jpts.27.3813
28. Bade M, Cobo-Estevez M, Neeley D, et al. Effects of manual therapy and exercise targeting the hips in patients with low-back pain—A randomized controlled trial. Journal of Evaluation in Clinical Practice. 2017; 23(4): 734-740. doi: 10.1111/jep.12705