https://doi.org/10.54141/psbd.1252481

PAMUKKALE JOURNAL OF SPORT SCIENCES
ISSN: 1309-0356
dergipark.org.tr/en/pub/psbd

Pamukkale J Sport Sci, 14(2), 192-205, 2023 Research Article

Do Oculomotor Exercises Improve Balance, Dynamic Visual Acuity and Performance in Female Volleyball Players? A Randomized Controlled Clinical Trial

Elif Aleyna YAZGAN[1] Pınar KAYA[1*]

[1]*Institute of Health Sciences, Physiotherapy and Rehabilitation Department, Istanbul Medipol University, Istanbul, Türkiye*

Keywords
Athletic performance,
Balance,
Visual acuity,
Volleyball

Article History
Received 17 February 2023
Revised 21 June 2023
Accepted 21 July 2022
Available Online 28 August 2023

* **Corresponding Author**:
Pınar KAYA
E-mail Address:
pkaya@medipol.edu.tr

ABSTRACT

Athletes must develop not only their physical and motor capabilities but also their visual and perceptual-cognitive skills to support their performance. This study investigated the effects of oculomotor exercises (OMEs) on elite female volleyball players' dynamic visual acuity (DVA), balance, and vertical jump performance (VJP). Fifty-two female volleyball players were allocated to two groups: the intervention group (IG, n=26) that received OMEs twice a day, six days a week for four weeks in addition to their daily training, and the control group (CG, n=26) that, only continued their daily training. All participants were assessed with the Flamingo Balance Test (FBT), Y Balance Test (YBT), Clinical DVA Test, and Vertical Jump Test (VJT) before and after the study. After the study, FBT, DVA, and YBT posteromedial values in IG improved significantly, but VJP did not change. The results for CG showed no improvements. After the study only FBT score differences were found between the groups. OMEs in volleyball players can help to improve balance by improving DVA and balance. Future research should investigate the effects of volleyball-specific visual training on improving performance skills.

Citation: Yazgan A. E. and Kaya Ciddi, P. (2023). Do Oculomotor Exercises Improve Balance, Dynamic Visual Acuity and Performance in Female Volleyball Players? A Randomized Controlled Clinical Trial. *Pamukkale Journal of Sport Sciences*, 14(2), 192-205. https://doi.org/10.54141/psbd.1252481

INTRODUCTION

Visual skill in sports encompasses a wide range of abilities, from basic ball tracking to the capacity to anticipate an opponent's next move, and it plays a significant part in practically all sports and sports-specific skills (Hrysomallis, 2011). Increased dynamic visual acuity (DVA), balance, and postural control are crucial since changing postures often, especially in fast-ball sports, demands re-analyzing the visual information gained from the new position (Agostini et al., 2013). DVA is the capacity to assess the spatial features of a moving object when the head is fixed and of an immobile object when the head is moving (Palidis et al., 2017).

Volleyball is a dynamic sport involving quick adjustments in reactionary actions, including direction, deception, stopping, and perception. Motor abilities such as reaction time (RT), hand-eye coordination, strength, speed, and endurance are anticipated to be at a high level to adjust to these changes (İbiş et al., 2015). Ocular mobility must operate properly while defending to react appropriately and in time to the opposing team's attack. Constant eye movement is required to follow the ball across the playing field (Piras et al., 2010). According to studies (Piras et al., 2010; Trecroci et al., 2021), professional volleyball players have better visual skills than non-athletes. They focus more on the setter's hands and the initial pass trajectory, ignoring the ball trajectory. Instead, the non-athletes follow the entire path of the ball (Piras et al., 2010). According to research on the visual abilities of volleyball players at various levels, advanced players performed visually better than beginners and intermediate players (Jafarzadehpur et al., 2007).

Athletes need to develop their physical and motor skills and their visual and perceptual-cognitive abilities to enhance performance improvement (Formenti et al., 2022; Hadlow et al., 2018; Knudson & Kluka, 1997). Few studies have examined the impact of non-sport-specific visual skills training on athletes' performance and whether visual skills may be improved via regular practice in athletes (Knudson & Kluka, 1997; Morimoto et al., 2011). Components of oculomotor exercises (OMEs), a visual exercise, include fixation, saccadic movements, smooth pursuit, and optokinetic and vestibular movements. Such primary and slower tracking movements of the eyes are important and necessary in many sports (Rodrigues et al., 2015). As far as we know, no study examines the effectiveness of these visual exercises in volleyball. In this study, we examined the impact of OMEs on the DVA, balance, and vertical jump performance

(VJP) of volleyball players. The hypothesis is that practicing visual skills may improve volleyball players' DVA, balance, and VJP.

METHODS

Study Design

The current study is a randomized clinical trial. The study was ethically approved by the Istanbul Medipol University Non-Interventional Ethics Committee on 16.04.2020 with file number 10840098-604.01.01-E.14171 (ClinicalTrials.gov Identifier: NCT04852549). Written informed consent was obtained from all participants.

Study Group

The study included 52 elite female volleyball players who were 16 to 26 years old, competed in the same league, and continuously played the sport for at least three years. All participants had healthy vision and hearing and were checked by a doctor at the beginning of the season. The subjects had no recent history of upper or lower extremity injuries, drug use that would have affected neuromuscular function, or acute or particular pain that might have interfered with the study process. Participants with neuropathy, diabetic foot, vision issues like dizziness and refractive errors, and a history of ankle fractures and sprains during the previous six months were not included in this study. The flow diagram of the study is shown in Figure 1.

The sample size was calculated to be 52 elite volleyball players (26 per group) with the G*Power 3.0.10 program, using the mean and standard deviation of DVA percent change scores in two groups based on the research conducted by Morimoto et al. (2011) considering the significance level of 0.05, and a power of 80%. The participants were randomly allocated to groups in a 1:1 ratio; the intervention group (n=26) and the control group (n=26). An electronic random table created by a person unrelated to the study was used to prepare the contents of the opaque, sealed envelopes used for randomization.

The intervention group received OMEs in addition to their daily training routines twice daily in the morning and evening, six days per week for four weeks (Minoonejad et al., 2019; Morimoto et al., 2011). They performed the evening exercises under the supervision of a physiotherapist, and all exercises were seated in a group before their daily training in the sports club. They were instructed to perform the exercises in the mornings at home. The participants received a pamphlet with the exercises (Figure 2), also demonstrated before. Their compliance was checked over the phone via a WhatsApp group message; they were prompted to perform the exercises, asked if they had done so, and noted. The control group continued their routine training for four weeks.

Figure 1
Flow diagram of participants

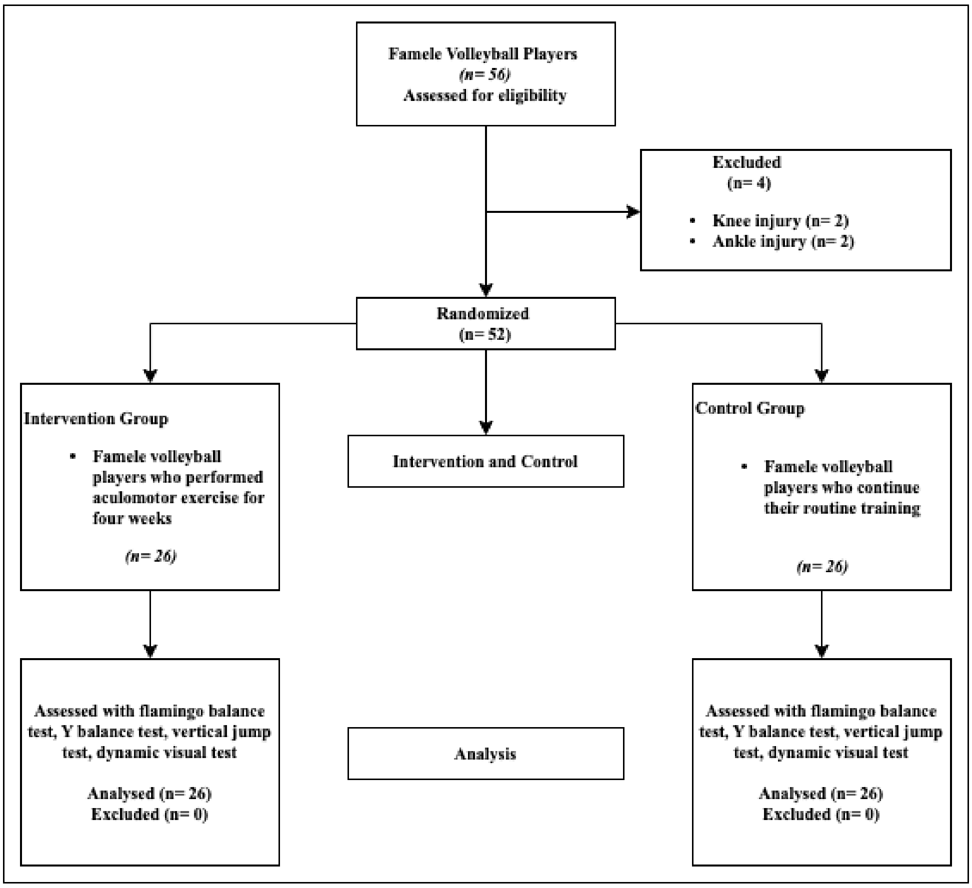
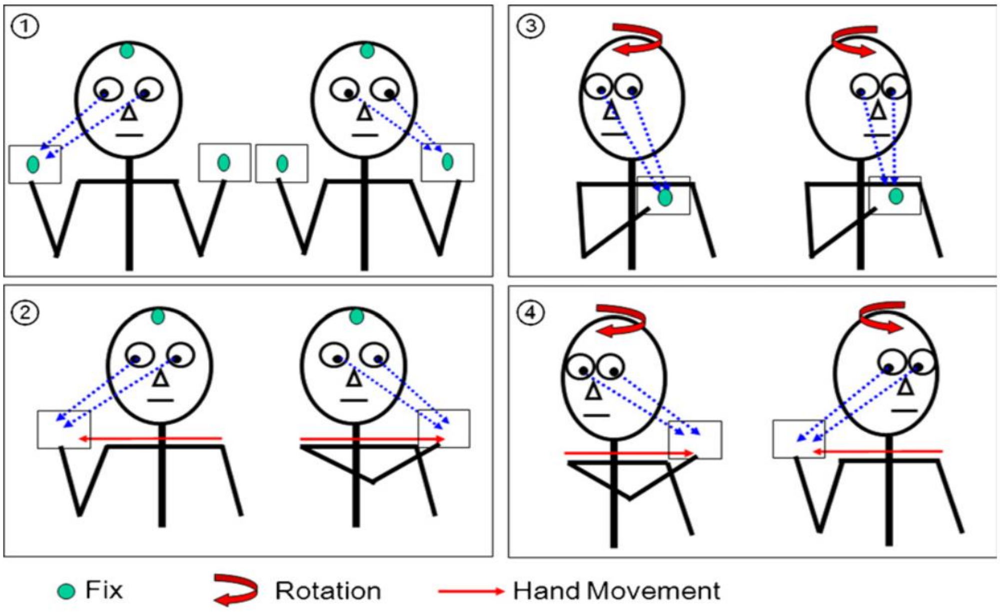


Figure 2
Oculomotor exercises and gaze stability exercise illustrations



Data Collection Tool

Age, height, weight, body mass index, volleyball age, training frequency per week, and daily training time of the participants were recorded. The same physiotherapist who was blind to groups conducted all assessments before and after the study.

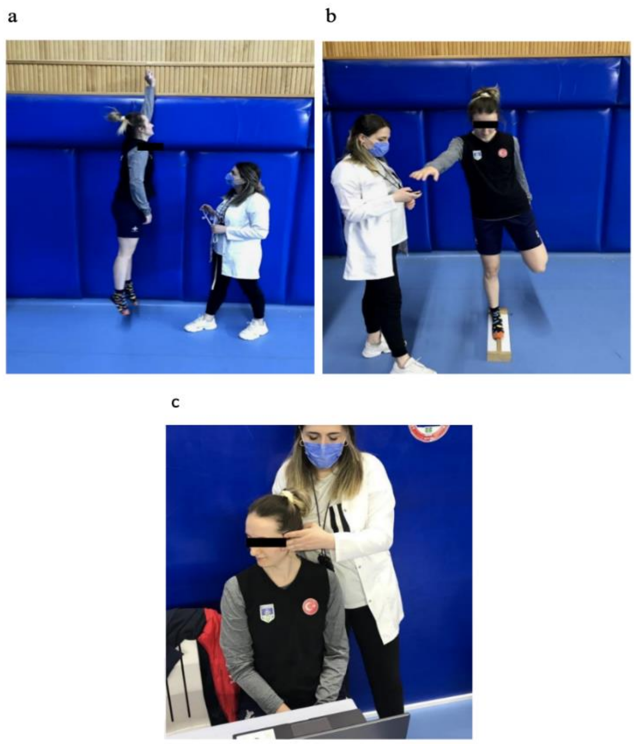
The Flamingo Balance Test (FBT) was used to evaluate participants' static balance. The test was conducted with a wooden beam that was 50 cm long, 5 cm high, and 3 cm wide. Participants raised their upper extremities on the same side while attempting to stand and balance on their dominant leg while barefoot on the beam. The same side hand grasped the ankle of the other flexed leg. The number of failures to maintain the position for one minute was recorded (Panjan & Sarabon, 2010).

The dynamic balance of participants was assessed with the Y Balance Test (YBT). Three measuring tapes were attached on the ground at 120-degree angles for anterior, posteromedial, and posterolateral YBT reach directions. Participants were instructed to stand barefoot on their dominant leg in the center of this YBT visual guide. For each YBT direction, they were instructed to extend their free limb as far as possible and tap the ground with the tip of their great toe. The test requires the participants to balance themselves, keep their hands on their hips, keep their standing feets' heels flat on the ground, touch the ground gently with their reach foot, and then return to the beginning position. The test was repeated three times for each direction along the taped outline on the ground with a 30-second break between each repetition. The average reach of trials was recorded in cm and used for analysis (Nelson et al., 2021; Plisky et al., 2006) (Figure 3).

Participants' VJP was assessed with the Vertical Jump Test (VJT), which measures the distance between the highest point reached during a vertical jump and the standing reach. The participants kept their feet on the ground while standing with their dominant side against the wall. To measure the standing reach, they extended their arms as far as possible and marked the wall with chalk on their fingertips. Then they jumped as high as they could vertically and left a chalk mark on the wall where their arms were extended at their highest point. The difference between the two markings was recorded in cm. The test was conducted three times with 60 seconds break between each trial, and the best jump was used for analysis (Marques et al., 2019; Sudhakar et al., 2018) (Figure 3).

The Clinical DVA Test (DVAT) was conducted on a laptop computer. The patient was seated in a chair, and a computer monitor was placed 70 cm away. A stimulus consisting of a string of 5 white numbers selected from a set of 0, 1, 2, 3, 4, 5, 6, 7, 8, or 9 was prepared on a black background using the Microsoft PowerPoint program. The 5-item number sequence was changed for each trial. The size of the number sequences prepared with the Tahoma font was changed from 12 to 20 points in 2-point increments (Herdman et al., 1998; Hillman et al., 1999; Roberts et al., 2006). Each participant received 10 slide trials, with the text size varying at random for each trial and each font size being repeated twice. In order to calculate the DVA, the participant was asked to perform the voluntary head rotation movement task in the horizontal plane. A 2.0 Hz auditory cue was presented with a metronome to perform voluntary head movement at a specified frequency (Roberts et al., 2006). The participant was instructed to rotate their head voluntarily at the same frequency as the auditory cue and at an angle of approximately 70° (Minoonejad et al., 2019; Morimoto et al., 2011). Each of the five numbers displayed in a trial was requested for a verbal report from the participant. In order to report the stimulus, the participant had 5 seconds before a new trial with a different set of numbers displayed. The average test time per patient was approximately 3 minutes. The number of accurate responses determined the person's dynamic vision score. Each trial's accurate response counts were collected, and the accuracy percentage for each font size was calculated. Each correct trial item accounted for 2% of the overall accuracy percentage. Before the test, it was proven that all participants could read the smallest font, 12 points, without moving their heads at a distance of 70 cm (Figure 3; Herdman et al., 1998; Roberts et al., 2006).

Figure 3
Demonstration of applying (a) Y Balance Test, (b) Vertical Jump Test, (c) The Clinical DVA Test



Exercises

The OMEs that were previously described by Herdman et al. (1998) were used. The exercises were (1) saccadic eye movement: The participant holds two colored objects in each hand on the right and left sides and moves the eyes horizontally between two fixed targets while maintaining a steady head position. The participant is asked to look at the object in the right hand and count to 10 while keeping his head in the middle position without rotating, then repeat the exercise on the left side. (2) smooth pursuit: The participant moves a colored object with the right hand horizontally, keeping the head stable in the midline position without rotating, and follows the object with the eyes. The participant is asked to keep their eyes on the object as it moves it in both directions on the horizontal plane. (3) adaptation X1: The participant fixes the eyes on the steady object and rotates the head horizontally from side to side. The participant is instructed to rotate the head horizontally while holding the object in the right hand, on the left side of the body, with the eyes locked on the object. (4) adaptation X2: The participant maintains eye contact with the target while moving the head and the target horizontally in opposition (Figure 2). The participant is instructed to fix their gaze on the colored object in their right hand while simultaneously moving their head and object in opposing directions (Minoonejad et al., 2019; Morimoto et al., 2011). The participant held the target in their palm, around 30 cm from their eyes. During the exercises, participants were encouraged to move the target or their head as quickly as possible while keeping a focused gaze on the target. During the first week, participants performed all exercises in a sitting position for ten minutes each in the morning and the evening. With a 5 second break between each exercise, four exercises were performed in a single set. Two sets per week increased the number of sets for the remaining three weeks. Each set was followed by a 10-second rest period (Minoonejad et al., 2019; Morimoto et al., 2011) (Figure 2).

Data Analysis

IBM SPSS (Statistical Package for Social Sciences) Statistics 22 package program was used to evaluate the data. The Shapiro-Wilk test was used to determine the normality distribution. Data analysis was determined using the in-group "Wilcoxon Test" and the intergroup "Mann-Whitney U Test." Statistical significance was set at $p < 0.05$ for all analyses. The effect sizes were assessed with "Cohen's d" to investigate the clinical significance of the changes caused by the intervention and post-treatment data results between the intervention and control groups. Effect size (d) was interpreted as weak if the value of "d" ≤0.5, medium if 0.51-0.79, large if 0.8, and very large if more than 1 (Cohen, 1992).

RESULTS

As seen in Table 1, the intervention group's FBT, DVAT, and YBT posteromedial values significantly increased following OMEs intervention in addition to their daily training ($p<0.05$). The VJT scores of the participants in the intervention group did not change significantly ($p>0.05$, Table 2). In the control group, who only continued their daily training, DVA values decreased significantly ($p<0.05$) at the end of the fourth week. At the same time, other parameters did not change significantly ($p>0.05$, Table 2). Only the FBT results between the groups following treatment showed a statistically significant difference ($p<0.05$).

Table 1.
Comparison of Participant's Characteristics at Baseline

Characteristic	IG (n = 26) Mean±SD	CG (n = 26) Mean±SD	*P*-value
Demographic features			
Age (year)	18.58 ± 2.99	18.46 ± 2.10	0.660
Height (cm)	175.42 ± 6.99	175.77± 7.65	0.866
Weight (kg)	62.08 ± 7.07	63.58 ± 7.64	0.466
Volleyball Age (year)	8.46 ± 4.17	7.65 ± 2.36	0.782
Daily training time (hour)	2,04 ± 0,48	2,02 ± 0,43	0.779
Training frequency per week (n)	5,12 ± 0,99	5,08 ± 1,01	0.900
Outcome measures			
FBT (n)	3.61 ± 2.71	4.96 ± 4.19	0.370
DVA (%)	81.46 ± 19.48	83.61 ± 11.11	0.707
YBT Anterior (cm)	84.39 ± 9.00	82.50 ± 8.59	0.280
YBT Posteromedial (cm)	89.26 ± 9.88	90.62 ± 10.63	0.280
YBT Posterolateral (cm)	96.58 ± 11.04	98.32 ± 8.66	0.510
VJT (cm)	34.00 ± 4.73	31.93 ± 3.88	0.161

Note. IG, Intervention Group; CG, Control Group; SD, Standard deviation; X, Average; *Mann Whitney U; FBT, Flamingo Balance Test; YBT, Y Balance Test; VJT, Vertical Jump Test; DVA, Dynamic Visual Acuity; Statistical significance limit p<0.05.

Table 2
Within and Between Group Differences for Outcome Measures

Outcome Measures	Group	Baseline Mean ± SD	Post-treatment Mean ± SD	Difference from post-treatment to baseline Mean ± SD	*P*-value within group	*P*-value between-group at post-treatment	E.S. (d)
FBT (n)	IG (n = 26)	3,61 ± 2,71	2.46 ± 2.40	-1.15 ± 1.08	**<0.001****	**0.007***	1.064
	CG (n = 26)	4.96 ± 4.19	5.00 ± 4.05	0.03 ± .60	0.739		0.064
YBT Anterior (cm)	IG (n = 26)	84.39 ± 9.00	85.16 ± 8.58	0.77 ± 3.74	0.125	0.191	0.205
	CG (n = 26)	82.50 ± 8.59	82.44 ± 8.80	-0.06 ± 1.05	0.567		0.058
YBT Posteromedial (cm)	IG (n = 26)	89.26 ± 9.88	91.36 ± 9.25	2.10 ± 3.50	**0.001****	0.993	0.645
	CG (n = 26)	90.62 ± 10.63	90.25 ± 10.65	-0.37 ± 1.40	0.198		0.256
YBT Posterolateral (cm)	IG (n = 26)	96.58 ± 11.04	96.45 ± 9.61	-0.13 ± 3.80	0.125	0.510	0.034
	CG (n = 26)	98.32 ± 8.66	98.26 ± 8.40	-0.05 ± 1.84	0.731		0.029

Table 2 (Continued)

Outcome Measures	Group	Baseline Mean ± SD	Post-treatment Mean ± SD	Difference from post-treatment to baseline Mean ± SD	*P*-value within group	*P*-value between-group at post-treatment	E.S. (d)
VJT (cm)	IG (n = 26)	34.00 ± 4.73	34.13 ± 4.52	0.14 ± 1.40	0.889	0.309	0.098
	CG (n = 26)	31.93 ± 3.88	32.65 ± 3.89	0.87 ± 0.65	0.420		1.338
DVA (%)	IG (n = 26)	81.46 ± 19,48	85.53 ± 16.38	4.07 ± 4.68	**<0.001****	**0.044***	0.869
	CG (n = 26)	83.61 ± 11.11	81.84 ± 11.50	-1,76 ± 2.38	**0.001****		0.739

Note. IG, Intervention Group; CG, Control Group; SD, Standard deviation; E.S., Effect Size; FBT, Flamingo Balance Test; YBT, Y Balance Test; VJT, Vertical Jump Test; DVA, Dynamic Visual Acuity; Statistical significance limit p<0.05; *p<0.05; **p<0.001.

DISCUSSION

This study demonstrated that using OMEs for four weeks can help elite volleyball players develop skills like balance and DVA, but no differences were found in VJT. It has been shown that DVA, as determined by the clinical visual acuity test, can be improved in healthy individuals and female basketball players after a 4-week OMEs intervention (Minoonejad et al., 2019; Morimoto et al., 2011). Many sports, such as volleyball, where players must constantly track the ball with their eyes and maintain ocular mobility, depend on vision competence (Piras et al., 2010). With OMEs for four weeks, DVA in female volleyball players improved in the current study. Our findings suggest that including OMEs in volleyball players' daily training may help them improve their visual skills.

The integration of somatosensory, visual and vestibular inputs achieves postural stability. Disruption of sensory integration can lead to balance problems and increase the likelihood of injury in athletes (Hammami et al., 2014). The vestibular system, part of sensory integration, helps maintain visual fixation on an object during head and body movements and works with the visual system to maintain postural balance (Dewan et al., 2023). Postural stability may not be maintained when there is decreased and incorrect information in one of the vestibular and visual systems (Abekawa et al., 2022). Studies have reported that vestibular rehabilitation components such as contrast sensitivity and dynamic visual acuity are determinants of postural sway (Lord & Menz, 2000).

The literature has reported that the visual system plays a fundamental role in various athletic activities and sport-specific balance skills for athletes (Hrysomallis, 2011; Hammami et al., 2014; Koide et al., 2019). In studies conducted with different athletes, it has been shown that visual skills are practical on both static and dynamic balance (Hammami et al., 2014; Koide et al., 2019). In our study, we assessed the dynamic balance of the participants with YBT and the static balance with FBT, which are easy to apply and often used in many sports branches and volleyball players (Daneshjoo et al., 2012; Çınar-Medeni et al., 2016).

In previous studies, OMEs applied for four weeks improved postural stability in healthy young adults (Morimoto et al., 2011) and positively affected stability limits in female basketball players (Minoonejad et al., 2019). As an underlying mechanism, it has been reported that the OMEs can provide visual and vestibular stimulation and improve the function of the vestibular system and postural stability depending on the neural adaptation in the cerebellum (Minoonejad et al., 2019; Morimoto et al., 2011). To our knowledge, this is the first study that investigates the OMEs' effect on balance in volleyball players. Our findings indicate that OMEs can improve the static and dynamic balance skills of elite female volleyball players, as measured by FBT and YBT. The compatibility of the results of our study with previous studies suggested that it may be beneficial to include OMEs in training programs to improve balance skills, which is an important performance parameter in volleyball athletes.

Sports such as basketball, football, and volleyball require a multisensory integration, including exteroceptive, proprioceptive, and vestibular, due to time-dependent requirements during competition (Asslender & Robert, 2014). In sports, multisensory integration often contributes to strength development, helping to adjust the timing, direction, and magnitude of the ground reaction force applied across the lower extremity (Louder et al., 2019). To position the body in space for vertical jumping, landing, sprinting, and cutting performance action, multiple sensory integrations, including the visual system, must be activated (Louder et al., 2019). It was stated that the visual system is a crucial input channel for multi-sensory integration and that it can be strengthened through visual training to help with sensorimotor control of deep jump performance (Kroll et al., 2020; Zeinalzadeh et al., 2018).

Minoonejad et al. investigated the effect of OMEs training applied to female basketball players for four weeks only on postural stability (Minoonejad et al., 2019). It has been reported that explosive muscle strength is one of the determinants of performance in many individual and team sports (Marcovic, 2007). Researchers have frequently used the vertical jump as a valid and reliable test for assessing the explosive power of the athlete's lower limbs to determine their training performance and abilities (Marcovic, 2007). In our study, there was no improvement in the vertical jump height of female volleyball players with the 4-week OMEs we applied to female volleyball players. Professional baseball players' visual skills were related to their batting performance, and traditional vision training improved batting performance in college baseball players (Laby et al., 1996; Clark et al., 2012). Formenti et al. showed that the assessment of volleyball-specific skills and cognitive functions, including visual tasks, are essential in distinguishing players from different levels of competition (Formenti et al., 2022). Kroll et al. found that female volleyball players' deep jump performance assessed with the force platform improved when they underwent stroboscopic vision training (Kroll et al., 2020). Zhou et al. demonstrated that although structured and non-sport-specific vision training improved cognitive performance, it did not impact volleyball players' sport-specific skills (Zhou et al., 2020). OMEs are not specific to volleyball, which may be why they did not enhance volleyball players' vertical jump abilities in our study. Future research should investigate the effects of volleyball-specific visual training on improving performance skills. Our study's limitations include the short training duration, lack of evaluation of long-term effects, lack of volleyball-specific visual exercises, and lack of technology-based assessment of balancing skills.

CONCLUSION

This study demonstrated that OMEs in volleyball players can enhance balance and DVA. Visual skill training can be included in volleyball players' daily routine training. Future studies must investigate the effects of sports-specific visual skill training on improving performance in volleyball players. There is a need for the use of testing methodologies consistent with the use of the field, in which volleyball-specific visual tracking is evaluated about field performance. We recommend that future researchers choose sports-specific tests, such as a drill for volleyball players to track the ball across a field.

Author contributions

The first author collected data, the first and second authors contributed to the study design. All authors analyzed the data, revised the manuscript and contributed to the interpretation of the results. The second author contributed to validation of the methodology of this study, the supervision and critical reviewing of the original draft. All authors have read and approved the final version of the manuscript.

Declaration of conflict interest

No potential conflict of interest was reported by the authors.

REFERENCES

Abekawa, N., Doya, K., & Gomi, H. (2022). Body and visual instabilities functionally modulate implicit reaching corrections. *iScience*, *26*(1), 105751. https://doi.org/10.1016/j.isci.2022.105751

Agostini, V., Chiaramello, E., Canavese, L., Bredariol, C., & Knaflitz, M. (2013). Postural sway in volleyball players. *Human Movement Science*, *32*(3), 445-456. https://doi.org/10.1016/j.humov.2013.01.002.

Clark, J. F., Ellis, J. K., Bench, J., Khoury, J., & Graman, P. (2012). High-performance vision training improves batting statistics for University of Cincinnati baseball players. *PloS One*, *7*(1), e29109. https://doi.org/10.1371/journal.pone.0029109

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1037//0033-2909.112.1.155

Çinar-Medeni Ö., Colakoglu F. F., Yüce K, Ipekoğlu G, & Baltaci G. (2016). The relation between knee muscle strength and performance tests in orienteering athletes. *The Journal of Sports Medicine and Physical Fitness*, *56*(111261), 1261-1268.

Daneshjoo, A., Mokhtar, A. H., Rahnama, N., & Yusof, A. (2012). The effects of comprehensive warm-up programs on proprioception, static and dynamic balance on male soccer players. *PloS one*, *7*(12), e51568. https://doi.org/10.1371/journal.pone.0051568

Dewan, B. M., James, C. R., Kumar, N. A., Burgess, N., Zupancic, S., & Sawyer, S. F. (2023). Adaptation in motor strategies for postural control associated with sensory reweighting. *Human movement science*, *89*, 103098. https://doi.org/10.1016/j.humov.2023.103098

Formenti, D., Trecroci, A., Duca, M., Vanoni, M., Ciovati, M., Rossi, A., & Alberti, G. (2022). Volleyball-specific skills and cognitive functions can discriminate players of different competitive levels. *Journal of Strength and Conditioning Research*, *36*(3), 813-819. https://doi.org/10.1519/JSC.0000000000003519

Hadlow, S. M., Panchuk, D., Mann, D. L., Portus, M. R., & Abernethy, B. (2018). Modified perceptual training in sport: a new classification framework. *Journal of Science and Medicine in Sport*, *21*(9), 950-958. https://doi.org/10.1016/j.jsams.2018.01.011

Hammami, R., Behm, D. G., Chtara, M., Ben Othman, A., & Chaouachi, A. (2014). Comparison of static balance and the role of vision in elite athletes. *Journal of human kinetics*, *41*, 33–41. https://doi.org/10.2478/hukin-2014-0030

Herdman, S. J., Tusa, R. J., Blatt, P., Suzuki, A., Venuto, P. J., & Roberts, D. (1998). Computerized dynamic visual acuity test in the assessment of vestibular deficits. *Otology & Neurotology*, *19*(6), 790-796.

Hillman, E. J., Bloomberg, J. J., McDonald, P. V., & Cohen, H. S. (1999). Dynamic visual acuity while walking in normals and labyrinthine-deficient patients. *Journal of Vestibular Research*, *9*(1), 49-57. https://doi.org/10.3233/VES-1999-9106

Hrysomallis C. (2011). Balance ability and athletic performance. *Sports medicine (Auckland, N.Z.)*, *41*(3), 221–232. https://doi.org/10.2165/11538560-000000000-00000

Jafarzadehpur, E., Aazami, N., & Bolouri, B. (2007). Comparison of saccadic eye movements and facility of ocular accommodation in female volleyball players and non-players. *Scandinavian journal of medicine & science in sports*, *17*(2), 186–190. https://doi.org/10.1111/j.1600-0838.2005.00535.x

Kroll, M., Preuss, J., Ness, B. M., Dolny, M., & Louder, T. (2020). Effect of stroboscopic vision on depth jump performance in female NCAA Division I volleyball athletes. *Sports biomechanics*, 1–11. *Advance online publication.* https://doi.org/10.1080/14763141.2020.1773917

İbiş, S., İri, R., & Aktuğ, Z. B. (2015). The effect of female volleyball players' leg volume and mass on balance and reaction time. *Journal of Human Sciences*, *12*(2), 1296-1308.

Knudson, D., & Kluka, D. A. (1997). The impact of vision and vision training on sport performance. *Journal of Physical Education, Recreation & Dance*, *68*(4), 17-24. https://doi.org/10.1080/07303084.1997.10604922

Koide, Y., Ueki, Y., Asai, Y., Morimoto, H., Asai, H., Johnson, E. G., Lohman, E. B., Sakuma, E., Mizutani, J., Ueki, T., & Wada, I. (2019). Differences in postural stability and dynamic visual acuity among healthy young adults in relation to sports activity: a cross sectional study. *Journal of physical therapy science*, *31*(1), 53–56. https://doi.org/10.1589/jpts.31.53

Laby, D. M., Davidson, J. L., Rosenbaum, L. J., Strasser, C., Mellman, M. F., Rosenbaum, A. L., & Kirschen, D. G. (1996). The visual function of professional baseball players. *American Journal of Ophthalmology*, *122*(4), 476-485. https://doi.org/10.1016/S0002-9394(14)72106-3

Louder, T., Thompson, B. J., Banks, N., & Bressel, E. (2019). A mixed-methods approach to evaluating the internal validity of the reactive strength index. *Sports*, *7*(7), 157. https://doi.org/10.3390/sports7070157

Lord, S. R., & Menz, H. B. (2000). Visual contributions to postural stability in older adults. *Gerontology*, *46*(6), 306–310. https://doi.org/10.1159/000022182

Marcovic, G. (2007). Poor relationship between strength and power qualities and agility performance. *Journal of Sports Medicine and Physical Fitness. 47*(3);276.

Marques, V., Coswig, V., Viana, R., Leal, A., Alves, F., Alves, A., & Gentil, P. (2019). Physical fitness and anthropometric measures of young Brazilian judo and wrestling athletes and its relations to cardiorespiratory fitness. *Sports*, *7*(2), 38. https://doi.org/10.3390/sports7020038

Minoonejad, H., Barati, A. H., Naderifar, H., Heidari, B., Kazemi, A. S., & Lashay, A. (2019). Effect of four weeks of ocular-motor exercises on dynamic visual acuity and stability limit of female basketball players. *Gait & Posture*, *73*, 286-290. https://doi.org/10.1016/j.gaitpost.2019.06.022

Morimoto, H., Asai, Y., Johnson, E. G., Lohman, E. B., Khoo, K., Mizutani, Y., & Mizutani, T. (2011). Effect of oculo-motor and gaze stability exercises on postural stability and dynamic visual acuity in healthy young adults. *Gait & Posture*, *33*(4), 600-603. https://doi.org/10.1016/j.gaitpost.2011.01.016

Nelson, S., Wilson, C. S., & Becker, J. (2021). Kinematic and kinetic predictors of Y-balance test performance. *International Journal of Sports Physical Therapy*, *16*(2), 371. https://doi.org/10.26603/001c.21492

Palidis, D. J., Wyder-Hodge, P. A., Fooken, J., & Spering, M. (2017). Distinct eye movement patterns enhance dynamic visual acuity. *PloS One*, *12*(2), e0172061. https://doi.org/10.1371/journal.pone.0172061

Panjan, A., & Sarabon, N. (2010). Review of Methods for the Evaluation of Human Body Balance. *Sport Science Review*, *19*, 131-63. https://doi.org/10.2478/v10237-011-0036-5

Piras, A., Lobietti, R., & Squatrito, S. (2010). A study of saccadic eye movement dynamics in volleyball: comparison between athletes and non-athletes. *The Journal of sports medicine and physical fitness*, *50*(1), 99–108.

Plisky, P. J., Rauh, M. J., Kaminski, T. W., & Underwood, F. B. (2006). Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *Journal of Orthopaedic & Sports Physical Therapy*, *36*(12), 911-919. https://doi.org/10.2519/jospt.2006.2244

Roberts, R. A., Gans, R. E., Johnson, E. L., & Chisolm, T. H. (2006). Computerized dynamic visual acuity with volitional head movement in patients with vestibular dysfunction. *Annals of Otology, Rhinology & Laryngology*, *115*(9), 658-666. https://doi.org/10.1177/000348940611500902

Rodrigues, S. T., Polastri, P. F., Carvalho, J. C., Barela, J. A., Moraes, R., & Barbieri, F. A. (2015). Saccadic and smooth pursuit eye movements attenuate postural sway similarly. *Neuroscience Letters*, *584,* 292-295. https://doi.org/10.1016/j.neulet.2014.10.045.

Sudhakar, S., Kirthika, S. V., Padmanabhan, K., Kumar, G. M., Nathan, C. S., Gopika, R., & Samuel, A. J. (2018). Impact of various foot arches on dynamic balance and speed performance in collegiate short distance runners: A cross-sectional comparative study. *Journal of Orthopaedics*, *15*(1), 114-117. https://doi.org/10.1016/j.jor.2018.01.050

Trecroci, A., Duca, M., Cavaggioni, L., Rossi, A., Scurati, R., Longo, S., Merati, G., Alberti, G., & Formenti, D. (2021). Relationship between cognitive functions and sport-specific physical performance in youth volleyball players. *Brain Sciences*, *11*(2), 227. https://doi.org/10.3390/brainsci11020227

Zeinalzadeh, A., Talebian, S., Naghdi, S., Salavati, M., Nazary-Moghadam, S., & Zeynalzadeh Ghoochani, B. (2018). Effects of vision and cognitive load on static postural control in subjects with and without patellofemoral pain syndrome. *Physiotherapy Theory and Practice*, *34*(4), 276-285. https://doi.org/10.1080/09593985.2017.1391360

Zhou, Y., Chen, C. T., & Muggleton, N. G. (2020). The effects of visual training on sports skill in volleyball players. *Progress in Brain Research, 253,* 201-227. https://doi.org/10.1016/bs.pbr.2020.04.002