Research Article

Spor Bilimleri Dergisi / Hacettepe Journal of Sport Sciences
DOI: https://doi.org/10.17644/sbd.1432708 2024,35(1), 36-45

The Effect of Oculomotor Exercises With Gaze Stabilization on Hand-Eye Coordination and Reaction Time in Table Tennis Athletes

Masa Tenisi Sporcularında Bakış Stabilizasyonlu Okülomotor Egzersizlerin El-Göz Koordinasyonu ve Reaksiyon Zamanına Etkisi

[1]Gülay ALTUNCU
ORCID No: 0000-0001-5007-1286

[1]Gülay ARAS BAYRAM
ORCID No: 0000-0001-5413-3712

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

ABSTRACT

The purpose of this study was to determine the effect of a 6 week oculomotor exercise program on hand-eye coordination, reaction time, visual perception and dynamic visual acuity with table tennis athletes. 50 table tennis players included in the study were randomly divided in to oculomotor exercise (OMEG, n=25) and control (CG, n=25) groups. While the two groups continued their routine tennis training programs, oculomotor exercises with gaze stabilization were applied to OMEG twice a day for 6 weeks via the WhatsApp application. Plate tapping test was used to evaluate the eye-hand coordination of the participants, reaction time test (number of hits and average reaction time) using the Blazepod device was used to evaluate reaction times, and forms A and B of the Trail Making Test (TMT-A ve TMT-B) were used to evaluate visual perception. Dynamic visual acuity test with powerpoint was used to evaluate the dynamic visual acuity of the participants. The paired t-test and two-sample t-test was executed to examine within and between the groups. The OMEG had significant improvements in hand-eye coordination, visual perception, reaction time and dynamic visual acuity ($p<0.05$). Significant differences between both groups were observed in the plate tapping test ($t=-3.560$, $p=0.01$) and TMT-A ($t=-2.276$, $p=0.027$). The 6 week oculomotor exercise program is able to improve hand-eye coordination and visual perception for table tennis athletes.

Keywords: *Eye hand coordination, Oculomotor exercise, Reaction time, Table tennis, Visual perception*

ÖZ

Bu çalışmanın amacı masa tenisi sporcularında 6 haftalık okülomotor egzersiz programının el-göz koordinasyonu, reaksiyon zamanı, görsel algı ve dinamik görme keskinliği üzerine etkisini belirlemektir. Araştırmaya dahil edilen 50 masa tenisi oyuncusu rastgele okülo-motor egzersiz (OMEG, n=25) ve kontrol (CG, n=25) gruplarına ayrıldı. İki grup rutin tenis antrenman programlarına devam ederken, okülo-motor egzersiz grubuna WhatsApp uygulaması üzerinden 6 hafta boyunca günde iki kez bakış stabilizasyonlu okülomotor egzersizler uygulandı. Katılımcıların el-göz koordinasyonunu değerlendirmek için disklere vurma testi, reaksiyon zamanını (vuruş sayısı ve ortalama reaksiyon zamanı) değerlendirmek için Blazepod cihazı ve görsel algıyı değerlendirmek için İz Sürme Testinin A ve B formları kullanıldı. Katılımcıların dinamik görme keskinliğini değerlendirmek için powerpoint ile dinamik görme keskinliği testi kullanıldı. Grup içi ve gruplararası analizlerde eşleştirilmiş t testi ve iki örnekli t testi uygulandı. OMEG'de el-göz koordinasyonu, görsel algı, reaksiyon zamanı ve dinamik görme keskinliğinde anlamlı iyileşmeler elde edildi ($p<0.05$). Disklere dokunma testi ($t=-3,560$, $p=0,01$) ve IST-A'da ($t=-2,276$, $p=0,027$) her iki grup arasında anlamlı fark gözlendi. Masa tenisi sporcularında 6 haftalık okülomotor egzersiz programı, el-göz koordinasyonu ve görsel algıyı geliştirebilir.

Anahtar Kelimeler: *El göz koordinasyonu, Okülomotor egzersiz, Reaksiyon süresi, Masa tenisi, Görsel algı*

Yazışma Adresi
Corresponding Address:

Gülay ARAS BAYRAM

Istanbul Medipol University

E-posta: garas@medipol.edu.tr

Geliş Tarihi (Received): 15.10.2023
Kabul Tarihi (Accepted): 09.02.2024

INTRODUCTION

The popularity of table tennis has grown steadily since it became an Olympic sport in the 1990s, reaching more than 300 athletes worldwide (Gu et al., 2019). Table tennis is a complex skill that involves the repeated combination of acceleration, deceleration, change of direction and balance control to produce optimal strokes (Girard et al., 2009). As a racket sport, table tennis consists of various strokes techniques that require high muscle strength, flexibility and body coordination (Johnson et al., 2006).

Objects in the visual environment often change the direction of movements in daily life. The main task of the visual system is to provide input for rapid reactions to these changes (Genova et al., 2000). In the 2nd century, Galen stated that there was a relationship between ball sports and the body and visual system (Hitzeman et al., 1993). In table tennis; visual and motor skills play an important role in determining the opponent's speed, stroke, fault rate, predicting the hit point of the next ball and determining the stroking style (Turhan et al., 2007).

The most important visual task of table tennis is that a person can always see the ball and keep it in focus. Looking at the right place at the right time is especially important, as it determines the destination of a player's ball and the timing of contact with it (Stein H et al 1981, Land et al., 2007). Table tennis is a sport that falls under the world's fastest ball game, and it has been reported that athletes need agility and excellent visual skills to perform at a high level (Rawat et al., 2019).

Visual perception is one of the most important factors for successful sports performance. For example; stroking the ball provides the ability to change the eye's adaptive state by using rapid and saccadic movements of the eyes to stay fixed on the ball, evaluate ball speed, and detect ball position (Magill et al., 2013).

In table tennis, the fact that the ball is very fast and the short distance it travels between opponents allows very little time to react and make stroke. A table tennis player must react correctly and quickly during the game to hit the ball in the right direction (Biernat et al., 2018). It should be evaluated as a whole as it includes the synergistic function of different systems such as hand-eye coordination, visual-vestibular system, understanding body position, sensoriomotor system including head and hand, and advanced cognitive memory. Hand-eye coordination is a very important component of sports performance (Ellisona et al., 2014; Crawford et al., 2004).

Gaze stability exercises are adaptation exercises based on the ability of the vestibular system to alter vestibulo-ocular reflex stimulation in response to head movement (Bhardwarj et al., 2014). The exercises have been reported to be used in various areas of optometric practice and to improve a wide variety of conditions, including vision problems, learning disabilities, dyslexia, asthenopia, myopia, sports performance, stereopsis, visual field defects, visual acuity, and general well-being (Rawstron et al., 2015).

To our knowledge, there are no studies on the effects of an oculomotor exercise program on hand-eye coordination, reaction time, visual perception and dynamic visual acuity levels in table tennis players. Therefore, this study aims to a 6 weeks oculomotor exercise program in table tennis athletes to determine the effects on hand-eye coordination, reaction time, visual perception and dynamic visual acuity levels.

METHOD

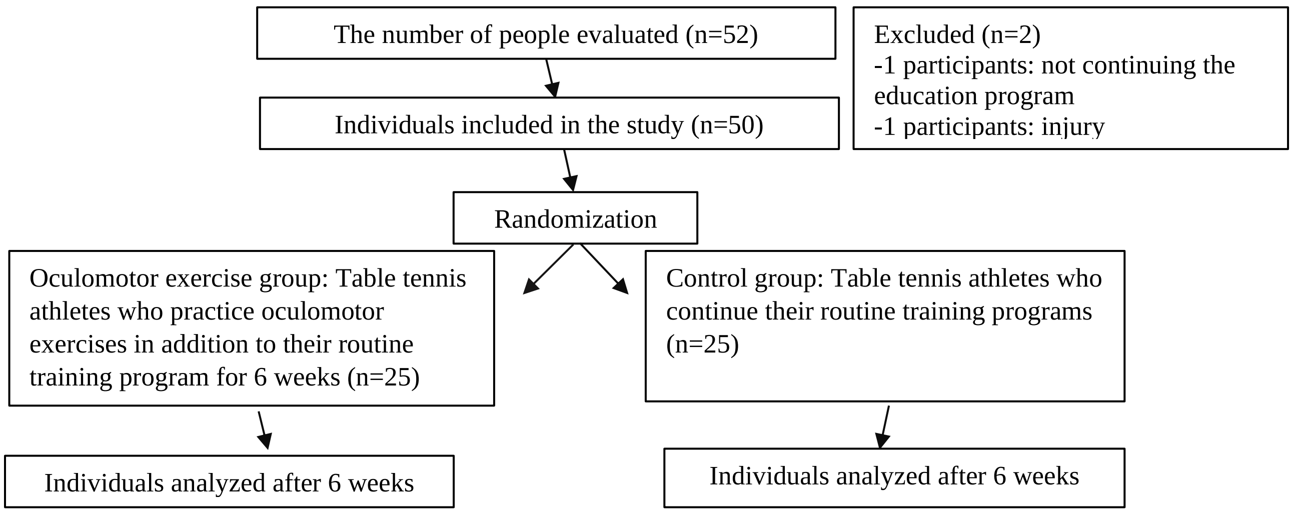
Research Design: The study's protocol was performed following the Helsinki Declaration and, approved by the Istanbul Medipol University Non-invasive Clinical Research Ethics Committee. A randomized, controlled, single-blinded study was conducted between October 2022 to April 2023 with 50 table tennis athletes from sports clubs. Of the 52 athletes initially invited, 2 were removed from the study due to: (a) sports injury (n=1) and does not want to continue the research (n=1), (Figure 1). Finally, 50 eligible athletes (10 female and 40 males) were randomly assigned to two groups based on a closed envelope method, including an Oculomotor Exercise Group (OMEG) 5 female and 20 male and Control Group (CG) 5 female and 20 male. All evaluations were performed by the same physiotherapist, blinded to the allocation.

Power analysis was performed with the G*Power program to determine the number of participants to be included in the study. In line with the results obtained, it was aimed to reach a minimum of 50 people in the study.

Statistical Analysis: Data were analyzed using IBM SPSS 25 (Chicago, IL, USA). Standard deviations and percentages are presented as descriptive statistics. The normal distribution of the data was confirmed using the "Shapiro-Wilk" tests. The paired t-test was executed to examine whether differences existed between the pre-intervention and post-intervention results for both the CG and OMEG. A two-sample t-test was conducted to determine the differences between the groups before and after the oculomotor exercises programme. Statistical significance was set at $p<0.05$.

Figure 1

Participants' Flow Diagram



The inclusion criteria were: (i) to be a table tennis athlete between the ages of 15-25; (ii) the absence of any drug use that affects neuromuscular function; (iii) to have normal vision and hearing sense; (iv) individuals who have completed the consent form. The exclusion criteria were: (i) strabismus or irreversible eye-related problems; (ii) having a vestibular disorder; (iii) have defects of vision myopia and hypermetropia; (iv) injuries requiring medical attention within the last 1 month; (v) refusal to participate in the study.

Data Measurements: The participants' age, gender, height, weight, body mass index, sports history and weekly training time are recorded.

The plate tapping test: 2 discs with a diameter of 20 cm and a rectangular plate of 10x20 dimensions were used. The discs were aligned on the table with a distance of 80 cm between them and a rectangular plate was placed equidistant from the discs.

The participant was asked to sit upright in front of the table and place the non-dominant hand on the rectangular plate and the dominant hand on the opposite disc. The time was started with the “Start” command and the athlete was asked to touch the discs alternately with the other hand from one disc to the other while the non-dominant hand was stationary. After completing 25 laps (50 touches in total), the "Stop" command was given and the time was recorded. As scoring, 1/10 of the time taken for 50 touches was recorded in seconds (Eurofit, 1988).

The blazepod reaction time test: It is connected to a smartphone via bluetooth connection. The “Random" mode was selected from the smartphone application. Blazepod discs were placed at 20 cm intervals in a triangular shape. While the participants were in the quadrupedal position, when the BlazePod device was illuminated, they touched the pods with their right and left hands, respectively. Participants started the test with the Start command given by the smartphone and ended the test with the Finish command sound. For 15 seconds, the number of times participants turned off the light during the activity (hits) and the average reaction time (avg) of all hits during the activity were recorded (de-Oliveira et al., 2021).

The trail making test (A-B): It consists of 25 circles with numbers distributed on the paper and has 2 parts (TMT A-B). In part A, there are numbers numbered between 1 and 25, and during the test, the athletes were asked to connect the circles by drawing lines consecutively and in the correct order. In part B, circles contain both numbers and letters. Athletes were instructed to connect the circles as quickly as possible by drawing a line without removing the pen from the paper, in a sequential order (1-A, 2-B, 3-C, etc.) in accordance with the order of numbers and letters. The time to complete each track was recorded in seconds (s), A and B (Corrigan and Hinkeldey, 1987).

The dynamic visual acuity test: A PowerPoint presentation consisting of a total of 10 slides was prepared, containing 5 numbers in the same font (all numbers were 12-20 points in size). Before starting the test, the ability of the participants to read 12 points from a distance of 70 cm without moving their head was checked while they were in a sitting position. The computer screen was placed at a distance of 70 cm. Participants were instructed to read the numbers appearing on the screen aloud by turning their head at a frequency of 2 Hz. The 2 Hz frequency was taught to all participants before the test and the physiotherapist assisted the participants in maintaining the 2 Hz frequency during the test. The number of correct answers was recorded for 5 seconds. The dynamic vision score of the person was determined according to the number of correct answers (Herdman et al., 1998).

Procedure: The athletes in the OMEG were asked to do the exercises at home in a sitting position twice a day (morning/evening) for 6 weeks. During the exercises, the participants were taught to focus on the target they held in their hands and to move the head and target as fast as they could see the image clearly. The exercises were shown to the participants in the first session and were performed with a physiotherapist. Subsequent sessions were followed remotely via the WhatsApp application. A training booklet with pictures of the exercises was distributed to the participants. The gaze stabilization oculomotor exercise program is as follows:

- Extraocular muscle warm-up: Eye tracking movements in different directions with closed and open eyes (moving the eyes right and left, up and down, right up and left down and circular).

- With the head in the middle position, two colored objects are held in both hands. Without turning the head, look at the object in the right hand and count to 10 and the same process is repeated for the object in the left hand.
- With the head fixed in the middle position, a colored object is held in the right hand. While moving the right hand from right to left without turning the head and returning, the object is followed by the eyes.
- With the head in the middle position, with the right hand on the left, a colored object is held in the hand. The eyes are fixed on the object and the head is turned to the right and left.
- With the head in the middle position, a colored object is held in the right or left hand. The eyes are fixed on the object and the arm and head are turned in opposite directions (Cole et al., 2022).

A rest period of 5 seconds was given between the two movements. Exercises were requested to be done 5 days a week, 2 times a day (morning/evening) and for 10 minutes, and control was provided via WhatsApp.

RESULTS

Sociodemographic characteristics of athletes are summarized Table 1. The groups had homogeneous characteristics (p> 0.05).

Table 1

Characteristics of Participants

Outcomes	**CG (n=25)**		**OMEG (n=25)**			
	Mean±SD	Min-Max	Mean±SD	Min-Max	t	p
Age(years)	18.4±3.27	15-25	17.6±2.93	15-25	0.955	0.344
Height (cm)	173.7±9.19	158-194	171.1±7.31	157-186	1.125	0.266
Weight (kg)	68.7±10.86	47-95	63.4±9.84	47-90	1.816	0.076
BMI (kg/m^2)	22.7±2.22	18.83-27.44	21.6±2.79	17.51-31.14	1.513	0.137
Number of workouts per week (hour)	3.2±1.19	2-6	3.5±1.05	2-6	-0.884	0.381
Number of daily workouts (hour)	2.9±0.70	2-4	3.0±0.68	2-4	-0.205	0.838
Experience (years)	6.1±3.13	3-15	5.4±3.39	3-17	0.737	0.465

CG: Control group, OMEG: Oculomotor exercises group, BMI: Body mass index (kg/m^2), $p<0.05$

Table 2 shows intragroup and intergroup analysis of plate tapping test, blazepod, ISTA-B, and dynamic visual acuity for the CG and OMEG after 6 weeks of oculomotor exercise programme. Significant differences between both groups were observed in the plate tapping test (t:-3.560, p:0.01), and the TMT-A (t:-2.276, p:0.027). Significant improvement was observed in the pre- and post-exercise all scores of the oculomotor exercise group ($p<0.05$).

Table 2

Intragroup and Intergroup Analysis of Plate Tapping Test, Blazepod, TMT-A,B, and Dynamic Visual Acuity

		Pre Test Mean±SD	Post Test Mean±SD	Change Score Mean±SD	Within groups t-(p)	Between groups t-(p)
Plate tapping test (s)	CG	111.9±20.59	107.2±17.65	4.7±11.77	2.022-(0.054)	-3.560-**(0.01*)**
	OMEG	116.8±19.61	100.4±11.87	16.4±11.27	7.261-**(<0.001*)**	
Blazepod reaction-stroke (n)	CG	26.4±4.51	28.1±4.18	1.7±3.10	2.772-**(0.011*)**	-1.556-(0.126)
	OMEG	25.9±4.23	29.3±3.22	3.4±4.42	3.850-**(0.001*)**	
Blazepod reaction-time (avg-s)	CG	523.6±131.84	500.1±72.26	23.5±104.81	1.122-(0.273)	-1.861-(0.069)
	OMEG	553.8±100.73	476.9±58.22	76.8±97.63	3.935-(**0.001***)	
TMT-A (s)	CG	17.8±6.99	17.2±4.90	0.6±3.05	0.959-(0.347)	-2.276-(**0.027***)
	OMEG	19.6±7.16	16.9±5.29	2.7±3.62	3.778-(**0.001***)	
TMT-B (s)	CG	46.5±17.30	42.0±12.91	4.5±7.75	2.890-(**0.008***)	-1.917-(0.061)
	OMEG	51.3±15.97	41.9±12.62	9.4±10.11	4.635-(**<0.001***)	
Dynamic visual acuity (n)	CG	45.0±2.12	46.1±1.45	1.1±1.53	-3.645-(**0.001***)	0.000-(1.000)
	OMEG	44.8±2.05	45.9±1.99	1.1±1.42	-3.934-(**0.001***)	

CG: Control Group, OMEG: Oculomotor Exercises Group, SD: Standart Deviation, TMT-A: Trail Making Test-A, TMT-B: Trail Making Test-B, *p<0.05.

DISCUSSION

In this study, we aimed to investigate the effects of gaze-stabilized oculomotor exercises applied for 6 weeks on the hand-eye coordination, reaction time, visual perception and dynamic visual acuity in table tennis players between the ages of 15-25. Positive developments were obtained in the hand-eye coordination and visual perception parameters of the athletes.

Azim Zadeh et al. (2022) stated that visual training alone is not sufficient for table tennis athletes and that a combination of visual and sports training will give the best results. Mallahi et al. (2014) investigated the effect of an eight-week sports skills training program combined with visual skills on table tennis and basketball players, and determined that the table tennis group performed better. In our study, oculomotor exercises were applied in addition to routine table tennis training, in line with the literature.

Sports vision is a new specialty in optometry and aims to improve and preserve visual function to improve sports performance (Garcia et al., 1993). Some evidence suggests that the visual system, like other body systems, can be improved through special visual training (Cross et al., 2013). In the literature, eye movement training has been reported to improve elite-level performance (Murray et al., 2017). Maman et al. (2011), found that in sports visual training conducted with 45 table tennis players for 8 weeks, the athlete performed better in terms of reaction time, depth perception, alignment estimation and jumping movements. In our study, it was concluded that 6 weeks of gaze stabilization oculomotor exercises provided significant improvement in hand-eye coordination and visual perception parameters in table tennis players. The significant result we obtained from our study suggests that athletes improve their performance by developing occipital neural synchronization mechanisms that enable them to show visual-motor performance during visuospatial demands (Percio et al., 2007).

Hand-eye coordination is one of the most important factors in table tennis (Faber et al.,2014). Ellison et al. (2015) reported that although there is a lack of evidence about the effectiveness of oculomotor programs applied to increase sports performance, interventions for athletes improve hand-eye coordination and provide visual improvements. In the study of Basiri et al. (2020), it was shown that visual training together with skill training is effective on reaction time and hand-eye coordination as well as motor skills in table tennis players. According to the results we obtained from our study, the scores of touching the discs in the oculomotor exercise group were significant compared to the control group showed improvement. In the oculomotor exercise group, the time to touch the discs was reduced. In our study, gaze stabilization oculomotor exercises improve hand-eye coordination, and the development of visual skills with oculomotor exercises mentioned in the studies in the literature is associated with motor actions. This suggests that it may be associated with an increase in sports performance (Appelbaum et al., 2011; Broadbent et al., 2014; Appelbaum and Ericsson 2016).

In a table tennis game hand reaction speed is required to receive and return the ball. If the athlete's reaction speed is low, it will be late for him to reach the incoming ball and it will be difficult for him to receive the ball and return it to the opponent. The athlete must have a fast reaction time and good stereopsis to process visual information about the approaching ball (Liskustyawati et al., 2016). Visual reaction time is a critical factor for determining the performance level of table tennis players (Zhu et al., 2019). Haydari et al. (2022) investigated the effect of two different sports vision training (in the context of hockey and not in the context of hockey) on the reaction time of hockey athletes; reported that although significant effects were observed in improving the reaction times of the athletes in both different trainings, sports vision exercises performed in the hockey-specific context showed a larger effect size. According to the results obtained from our study, no significant difference was found in the number of strokes and average stroke durations of the participants in the control and oculomotor exercise groups. This result may be associated with the short training period and the fact that the exercises we applied are not specific to table tennis.

Many researchers in game sports have included neuropsychological tests when designing studies in sports and movement-related environments (Hernández et al., 2019; Voss et al., 2010; Scharfen, et al.,2019). In our study, the visual perception of table tennis players was evaluated with the Tracking Test. Table tennis is an activity in which the interaction between visual perception knowledge and movement performance is actively carried out. The results we obtained in our study are that gaze stabilization oculomotor exercises provide statistical benefit in visual perceptual function (TMT-A) of table tennis players (Table 2). Pajoohesha et al. (2019) reported that sports vision training applied to 24 male karate athletes aged 10-12 improved visual-motor perception and sports performance. Anderson et al. (2021), evidence from their study shows that individual differences in TMT-A are mainly attributable to perceptual processing and motor programming speed and visual search proficiency.

The correlation between eye movement quality and dynamic visual acuity performance has important implications when developing rehabilitation or training programs such as post-traumatic brain injury or sports vision training (Hirano et al., 2018). Hiromi et al. (2010) showed that visual reaction time, ocular motor skills, and hand-eye coordination contributed to dynamic visual acuity in female table tennis players. Minoonejad et al. (2019) found that oculomotor exercises and gaze stability exercises showed improvements in active head rotation, dynamic visual acuity and postural stability in basketball players. The common conclusion from previous studies is that gaze stabilization exercises can greatly benefit active vestibulo-ocular reflex and dynamic visual acuity. The results obtained in our study showed that there was no significant difference between the oculomotor exercise group and the control group. However, some participants in both groups had an increase in dynamic visual acuity. This result obtained in our study may be due to the short follow-up period of the study. At the same time, the increase in dynamic visual acuity can be associated with the motor learning process (Petersa et al.,2013).

In our study, no significant difference was observed between the athletes table tennis experiences. Allen et al. (1996) stated in their study that the motor development of adolescent athletes slows down due to growth changes associated with puberty. Previous studies investigating dynamic visual acuity consistently report large effects of expertise, with expert athletes exhibiting better visual attention performance than novice players. (Heppe et al., 2016; Voss et al., 2010; Wechsler et al., 2021). The lack of significant improvement in dynamic visual acuity in our study suggests that this may be due to the athletes' lack of experience.

In our study, there are limitations such as unequal gender distribution of participants between groups, lack of long-term follow-up evaluations, and measurement methods are not specific to the table tennis sport.

CONCLUSION

Results of this study suggested that a 6 weeks oculomotor exercise programme could improve hand eye coordination and visual perception of table tennis athletes. However, oculomotor exercises also benefit reaction time and dynamic visual acuity after the intervention. Although these findings agree with those shown in the scientific literature, they should be taken cautiously. Our study is one of the limited studies investigating the effect of oculomotor exercises in table tennis players. In future studies, it is recommended to plan in such a way that long-term results are evaluated and oculomotor exercises can be adapted in the context of stroke techniques in table tennis.

Author Contribution

1. **Gülay ALTUNCU:** Idea/Concept, Design, Checking, Data Collection And Processing, Writing.
2. **Gulay ARAS BAYRAM:** Idea/Concept, Design, Checking, Data Processing, Analysis-Interpretation, Critical Review.

Information about Ethical Board Permission

Committee Name: Istanbul Medipol University Non-invasive Clinical Research Ethics Committee

Date: 13/03/2022

Sayı No: 261

KAYNAKÇA

1. **Appelbaum, L.G., Schroeder, J.E., Cain, M.S., and Mitroff, S.R. (2011).** Improved visual cognition through stroboscopic training. *Frontiers in Psychology, 28(2):276.* https://doi.org/10.3389/fpsyg.2011.00276.
2. **Appelbaum, L.G., and Erickson, G. (2016).** Sports vision training: A review of the state-of- the-art in digital training techniques. *International Review of Sport and Exercise Psychology, 11,160–89.* https://doi.org/10.1080/1750984X.2016.1266376
3. **Bhardwaj, V., and Vats, M. (2014).** Effectiveness of gaze stability exercises on balance in healthy elderly population. *International Journal of Physiotherapy and Research, 2(4):642-47.*
4. **Basiri, F., Farsi, A., Abdoli, B., and Kavyani, M. (2020).** The effect of visual and tennis training on perceptual-motor skill and learning of forehand drive in table tennis players. *Journal of Modern Rehabilitation, 14(1):21-32.* https://doi.org/10.32598/JMR.14.1.3
5. **Broadbent, D.P., Causer, J., Williams, A.M., and Ford, P.R. (2014).** Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science, 15,32231.* https://doi.org/10.1080/17461391.2014.957727
6. **Biernat, E., Buchholtz, S., and Krzepota, J. (2018).** Eye on the ball: table tennis as a pro health form of leisure-time physical activity. *International Journal of Environmental Research and Public Health, 15(4): 738.* https://doi.org/10.3390/ijerph15040738
7. **Corrigan, J.D., and Hinkeldey, M.S. (1987).** Relationships between parts a and b of the Trail Making Test. *Journal of Clinical Psychology, 43(4):402–9.*
8. **Crawford, J., Medendorp, W., and Marotta, J. (2004).** Spatial transformations for eye–hand coordination. *Journal of Neurophysiology, 92(1):10-9.* https://doi.org/10.1152/jn.00117.2004
9. **Cross, E.S., Stadler, W., Parkinson, J., Schütz-Bosbach, S., and Prinz, W. (2013).** The influence of visual training on predicting complex action sequences. *Human Brain Mapping, 34(2):467-86.* https://doi.org/10.1002/hbm.21450
10. **Durey, A., and Seydler, R. (1994).** Perfecting of a ball bounce and trajectories simulation software: in order to predict the consequences of changing table tennis rules. *International of Journal of Table Tennis, No:2.*
11. **Azim Zadeh, E., Ghasemi, A., and Gholami, A. (2016).** Effect of selected visual and sport training program on visual skills. *Motor Behavior, 7(22):15-32.*
12. **Ellisona, P.H., Sparksa, A., Murphy, P.N., Carnegiea, E., and Marchanta, D.C. (2014).** Determining eye–hand coordination using the sport vision trainer: an evaluation of test–retest reliability. *Research in Sports Medicine, 22(1):36-48.* https://doi.org/10.1080/15438627.2013.852090
13. **Eurofit. (1988).** European Tests of Physical Fitness, Council of Europe. *Committee for the Development of Sport, Rome.*
14. **Faber, I.R., Oosterveld, F.G., and Sanden, J.N. (2014).** Does an eye-hand coordination test have added value as part of talent identification in table tennis? A validity and reproducibility study. *PLoS ONE, 17;9(1).* https://doi.org/10.1371/journal.pone.0096748
15. **Garcia, T., Martin, Y., and Nieto, A. (1993).** Visión deportiva. Suplemento de la Revista Gaceta óptica. *Colegio nacional de ópticos-optometristas: Madrid, Spain.*
16. **Genova, B., Mateeff, S., Bonnet, C., and Hohnsbein, J. (2000).** Mechanisms of simple and choice reaction to changes in direction of visual motion. *Vision Research, 40:3049-58.* https://doi.org/10.1016/S0042-6989(00)00158-9
17. **Girard, O., and Millet, G.P. (2009).** Neuromuscular fatigue in racquet sports. *Physical Medicine and Rehabilitation Clinics of North America, 20:161-73.* https://doi.org/10.1016/j.pmr.2008.10.008
18. **Gu, Y., Yu, C., Shao, S., and Baker, J.S. (2019).** Effects of table tennis multi-ball training on dynamic posture control. *PeerJ Journals, 6: e6262.* https://doi.org/10.7717/ peerj.6262
19. **Heppe H, Kohler A, Fleddermann M, and Zentgraf K. (2016).** The relationship between expertise in sports, visuospatial, and basic cognitive skills. *Frontiers in Psychology, 7:904.* https://doi.org/10.3389/fpsyg.2016.00904
20. **Herdman, S.J., Tusa, R.J, Blatt, P., Suzuki, A., Venuto, P.J., and Roberts, D. (1998).** Computerized dynamic visual acuity test in the assessment of vestibular deficits. *Handbook of Clinical Neurophysiology, 19(6):790-6.*
21. **Hernández-Mendo, A., Reigal, R. E., López-Walle, J. M., Serpa, S., Samdal, O., Morales-Sánchez, V., and Falco, C. (2019). Physical** activity, sports practice, and cognitive functioning: The current research status. *Frontiers in Psychology, 10: 2658.* https://doi.org/10.3389/fpsyg.2019.02658
22. **Heydari, H., Badami, R., and Meshkati, Z. (2022).** Comparison of the effect of sports vision training with and without ınline hockey specific context on the speed and whole body reaction time of ınline hockey players. *Journal of Sports and Motor Development and Learning, 14(1):89-110.* https://doi.org/10.22059/jsmdl.2022.333255.1618
23. **Hirano, M. (2018).** *The validation of a novel dynamic visual acuity test, and examination of the effects of different factors on dynamic visual acuity.* [Unpublished Master Thesis, University of Waterloo].

24. **Hiromi, M., Kenji, Y., Takeshi, Y., and Tokio, T. (2010).** The characteristics of kinetic vision in women's table tennis players. *Doshisha journal of health & sports science, 2:26-37.*
25. **Hitzeman, S.A., and Beckerman, S.A. (1993).** What the literature says about sports vision. *Optometry Clinics, 3(1):145-69.*
26. John B. Allen. (1996). Table tennis and motor development. *International Journal of Table Tennis Science, No:3.*
27. **Johnson, C.D., Hugh, M.P., Wood, T., and Kibler, B. (2006).** Performance demands of professional male tennis players. *British Journal of Sports Medicine, 40(8):696–99.* http://dx.doi.org/10.1136/bjsm.2005.021253
28. **Cole, K.R., Goodman, K., and Volland, L. (2022).** Reporting of exercise dose and dosage and outcome measures for gaze stabilisation in the literature: a scoping review. *BMJ Open, 12(2): e049560.* https://doi: 10.1136/bmjopen-2021-049560
29. **Land, M. (2006).** Eye movements and the control of actions in everyday life. *Progress in Retinal and Eye Research, 25(3):296-324.* https://doi.org/10.1016/j.preteyeres.2006.01.002
30. **de-Oliveira, L.A., Matos, M.V., Fernandes, I.G., Nascimento, D.A., and da Silva-Grigoletto, M.E. (2021).** Test-retest reliability of a visual-cognitive technology (BlazePod™) to measure response time. *Journal of Sports Science & Medicine, 20(1):179.* https://doi: 10.52082/jssm.2021.179.
31. **Liskustyawati, H., Sulaiman, S., and Rachman, H.A. (2016).** The physical tests for 13-15 year old table tennis players. *The Journal of Educational Development, 4(2),192-200.*
32. **Magill, R., and Anderson, D. (2013).** Motor learning and control: Concepts and applications. 10th ed. New York City: Mc GrawHill Higher Education.
33. **Mallahi, A., Ghasemi, A., and Gholami, A. (2014).** Effect of visual and sport skills training on visual skills and sport performance among novice table tennis and basketball players. *Motor Behaviour, 5(14):129-45.*
34. **Maman, P., Biswas, S.K., and Sandhu, J.S. (2011).** Role of sports vision and eye-hand coordination in performance of table tennis players. *Brazilian Journal of Biomotricity, 5(2): 106-16.*
35. **Minoonejad, H., Barati, A.H., Naderifar, H., Heidari, B., Kazemi, A.S., and Lashay, A. (2019).** Effect of four weeks of ocular-motor exercises on dynamic visual acuity and stability limit of female basketball players. *Gait & Posture, 3, 286-290.* https://doi.org/10.1016/j.gaitpost.2019.06.022
36. **Murray, N.P., and Hunfalvay, M. (2017).** A comparison of visual search strategies of elite and non- elite tennis players through cluster analysis. *Journal of Sports Sciences, 35:241-46.* https://doi.org/10.1080/02640414.2016.1161215.
37. **Pajoohesha, P., Badamib, R., Nazakat, M., and Hosseinic, A. (2019).** The effect of sports vision training on visual-motor perception and performance in kata in the teenager. *International Journal of Motor Control and Learning, 1(2) 33-40.*
38. **Percio, C., Brancucci, A., Vecchio, F., Marzano, N., Pirritano, M., and Meccariello, E. (2007).** Visual event-related potentials in elite and amateur athletes. *Brain Research Bulletin, 74:104-12.* https://doi.org/10.1016/j.brainresbull.2007.05.011.
39. **Petersa BT, Helen S. Cohen, Haleh Sangi-Haghpeykar and Jacob J. Bloomberg (2013).** Effects of distance and duration on vertical dynamic visual acuity in screening healthy adults and people with vestibular disorders. *Journal of Vestibular Research,1; 23(6): 285–291.* https://doi.org/10.3233/VES-130502
40. **Rawstron, J.A., Burley, C.D., and Elder, M.J. (2005).** A systematic review of the applicability and efficacy of eye exercises. *Journal of Pediatric Ophthalmology & Strabismus, 42(2):82-8.* https://doi.org/10.3928/01913913-20050301-02
41. **Scharfen, H.-E., and Memmert, D. (2019).** Measurement of cognitive functions in experts and elite-athletes: A meta-analytic review. *Applied Cognitive Psychology.* https://doi.org/10.1002/acp.3526
42. **Stein, H., and Slatt, B. (1981).** Hitting blind, The new visual approach to winning tennis. *Beaufort, Newyork, 150-57.*
43. **Turhan, B., Mutlutürk, N., and Gençoğlu, A. (2007).** Masa tenisinde koordinatif oyun yetenekleri. 3. *Raket Sporları Sempozyumu Bildiri Kitapçığı, ss. 32-37, Kocaeli.*
44. **Voss, M.W., Kramer, A.F., Basak, C., Prakash, R.S., and Roberts, B. (2010).** Are expert athletes "expert" in the cognitive laboratory? A meta-analytic review of cognition and sport expertise. *Applied Cognitive Psychology, 4:812–826.* https://doi.org/10.1002/acp.1588
45. **Wechsler K, Bickmann P, Rudolf K, Tholl C, Froböse I, and Grieben C. (2021).** Comparison of multiple object tracking performance between professional and amateur esport players as well as traditional sportsmen. *International Journal of eSports Research, 1:1–17.* https://doi.org/10.4018/IJER.20210101.oa2
46. **Zhu, X.J., Li, Y.H., and Liu, L.Q. (2019).** Functional significance of stereopsis in Professional table-tennis players. *The journal of sports medıcıne and physıcal fitness, 59:1798–804.* https://doi.org/10.23736/s0022-4707.19.09300-9