Original Investigation

DOI: 10.4274/jarem.galenos.2025.34635
J Acad Res Med

Vestibular Exercises Combined with Table Tennis Exercises May Yield More Effective Outcomes: A Preliminary Randomized Study

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Cite this article as: Ersin K, Yeral C, Eti S, Şerbetçioğlu MB. Vestibular exercises combined with table tennis exercises may yield more effective outcomes: a preliminary randomized study. J Acad Res Med. [Epub Ahead of Print].

ABSTRACT

Objective: Classical vestibular (VEST) exercises for patients with dizziness are sometimes not beneficial enough. It is thought that table tennis exercises may be beneficial in these patients, especially to improve the VEST system and posture. The objective of our original study was to assess the impact of VEST exercises, when combined with table tennis exercises, as a fun and cost-effective method that can be comfortably performed at home, on body posture.

Methods: In this preliminary study, healthy subjects with balance scores close to normal were recruited. Conventional VEST exercises (CVE) (n=36) and CVE combined with table tennis (n=36) programs were performed on two different groups for 6 weeks. Individuals were evaluated with the Sensory Organization Test before and after the study.

Results: In the CVE combined with table tennis (CVE-TT) a statistically significant difference was found between Strategy 5 and 6, composite, and VEST data scores before and after the study ($p<0.05$). There was a statistically significant difference in preference data scores for Strategy 6 in the CVE group in the pre-post comparison ($p<0.05$), while there was a non-significant decrease in the CVE-TT group.

Conclusion: In this original study, the balance performance of the individuals is objectively improved after the CVE-TT exercises program compared to CVE exercises. For individuals with dizziness (e.g., residual dizziness), it will be more efficient and entertaining to use this new method at home instead of the classical rehabilitation program.

Keywords: Balance, Computerized dynamic posturography, table tennis, vestibular rehabilitation

INTRODUCTION

Balance is essential for many activities of daily living, and balance problems (e.g., falls) are major public health problems. To prevent falls, individuals must control their center of mass location over the base of support during both voluntary movements and in response to external, destabilizing forces (1). Postural stability is achieved by integrating vestibular (VEST), visual (VIS) and somatosensory inputs to produce a motor response (2). The VEST system plays various roles in postural control. The role it plays in the postural task varies according to the nature of the task and environmental conditions. Similarly, in situations where somatosensory information is less available and VIS information is not available at that moment, VEST information may play a dominant role in maintaining postural control (3).

VEST rehabilitation exercises improve quality of life by reducing the degree of handicap, improving the ability to perform daily tasks, and providing long-term postural stability. Rehabilitation programs offer a variety of benefits, including improvements in overall health and balance, a safer gait, and reduced disability due to dizziness (4). Rehabilitation strategies have been applied successfully in the last few decades to initiate central compensation of the tonus imbalance, and facilitate substitution in different types of peripheral VEST dysfunction (5).

Table tennis is an Olympic sport and one of the most widely played racquet sports. It requires complex visuospatial perception and movements, including balance control. Table tennis players have been shown to have shorter VIS reaction times, better executive functions and visuospatial working memory than healthy

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Received Date: 06.12.2024 **Accepted Date:** 26.05.2025
Epub: 02.07.2025

individuals (6). Recreational table tennis has been associated with improved bone health, physical function and muscle strength. Positive cognitive effects of table tennis training have also been demonstrated (7).

Christensen et al. (8) demonstrated that a 6-week VEST exercise program improved VEST function in healthy adolescents. Cone et al. (1) demonstrated in their study, which included 40 healthy young adults, that a 6-week Wii Fit training improved dynamic balance. These are rare studies with normal individuals. To our knowledge, there are no studies on the effect of VEST exercises combined with table tennis on balance.

There are studies in the literature demonstrating the effect of sports on balance (9). However, despite the findings, there are very few studies in which these sports, are added to balance exercises. In this study, we examined table tennis, a sport that has not traditionally been included in balance exercises. Since table tennis has a fun aspect and positive effects on multisensory systems, we hypothesized that combining it with conventional VEST exercises (CVE) would yield better results. Our study has a unique value in this respect.

METHODS

Study Population

The study was conducted between March 2023 and April 2023 on healthy individuals aged 18-21 years. The study was explained to each participant, and written informed consent was obtained. All described procedures were conducted following the Declaration of Helsinki. Ethical approval was obtained from the Non-Invasive Clinical Research Ethics Committee of İstanbul Medipol University Non-Interventional Clinical Research Ethics Committee Presidency University with the decision no: 380, date: 27.06.2018.

Nineteen female and nineteen male individuals (ages: 20.4±1.3 years) were included in the CVE group. Twenty female and sixteen male individuals (ages: 20.2±1.1 years) were included in the study group. The individuals did not have any major illness, such asotologic or neurologic pathology, or extensive experience in physical exercise. None of the test subjects was diagnosed with balance disorders, and none of them needed glasses, contact lenses, or hearing aids.

Sample Size and Randomization

Power analysis was performed using G*Power to ascertain whether the sample size would sufficiently detect significant differences. The power analysis revealed a power of 90% with an effect size of 0.50 at a significance level of 0.05, indicating that a sample size of 36 is required to achieve these parameters. However, since we have two groups, the minimum sample size is calculated as 36 multiplied by 2=72. The effect size equals 0.5 according to effect size index dz. After this, we randomly assigned a total of 40 patients to the CVE group and 40 patients to the CVE-TT group. A total of 6 people (4 in the CVE group and 2 in the CVE-TT group) dropped out of the study for personal reasons (Figure 1).

Balance Training Program

The exercise program of both groups consisted of three phases. Each phase of the exercise program was performed twice a week for six weeks. Exercises of both groups are shown in Tables 1 and 2. The exercises of the CVE-TT group are demonstrated in Figure 2. In this study, two cushions, one small ball, one table tennis racket and ball, one balance board, one pilates ball, and two pilates mats were used. The balance status of the individuals was evaluated with Computerized Dynamic Posturography (CDP) before and after the study.

Measurements of Postural Control

A NeuroCom Balance Manager (Natus Medical Inc., Seattle, WA) was used to assess postural stability. Sensory Organization Test (SOT) which is a subtests of CDP, was performed to objectively assess postural stability. This test is used to assess the individual's use of somatosensory, VIS, and VEST input to maintain balance.

Participants were secured in a safety harness and positioned barefoot on the NeuroCom Balance Manager, with their foot placement standardized relative to their height. Data collectors followed standardized written instructions for the SOT protocol, including verbal cues for each trial of each condition. Individuals stood with arms relaxed at their sides, looking straight ahead, as still as possible. Participants performed all six SOT conditions, repeating each 20-second trial three times. The individual is presented with six conditions of varying sensory input, including eyes open with fixed support (Condition 1); eyes closed with fixed support (Condition 2); sway surround with fixed support (Condition 3); eyes open with sway support (Condition 4); eyes closed with sway support (Condition 5); and sway surround with sway support (Condition 6). In this way, different SOT conditions create sensory discrepancies. At the end of the test, the systems (somatosensory, VIS, and VEST) that the patient actively uses while maintaining balance, the overall balance score [composite (COM)], and the preference for the VIS system while maintaining

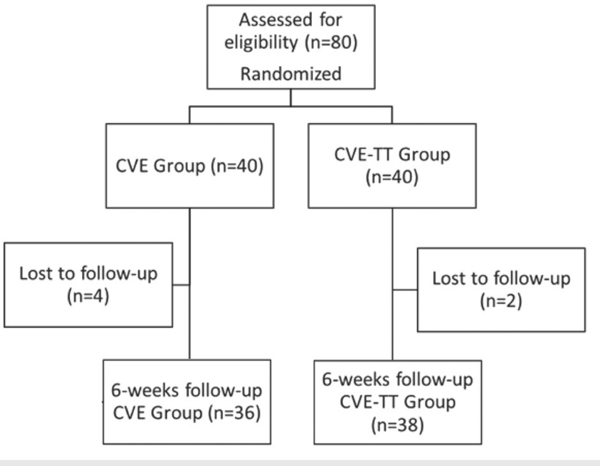

Figure 1. Participants at each stage of the trial
CVE-TT: Conventional vestibular exercises combined with table tennis

Table 1. Conventional vestibular exercises program

Exercise program 1 (1-2. week)
1. Walking back and forth on the soft surface (e.g. cushion, mat) with eyes closed.
2. Standing on one foot on firm surface.
3. Standing on a cushion, with eyes closed, and sitting down standing up continuously.
4. Shaking the head while standing on firm surface with gaze fixation (Rotates the head side to side horizontally with gaze fixed on a stationary target. Side-to-side head movement of w60 at a speed of 90/s, 1.5 hz).
5. Shaking the hand while standing on firm surface with gaze fixation (Extends one arm forward and make the thumb-target-up and turn the arm side to side while focusing on the thumb. Keep the head still and moves only the eyes).
EXERCISE PROGRAM 2 (3-4. week)
1. March in place with eyes closed.
2. Standing on the balance board with eyes open.
3. Shaking the head while standing on the soft surface (e.g. cushion, mat) with eyes closed.
4. Standing on the mat with one leg with hands on waist and eyes closed.
5. Walking back and forth on a soft surface (e.g. cushion, mat) with gaze fixation.
EXERCISE PROGRAM 3 (5-6. week)
1. Walking to the right and left with sharp or wide turns with eye closed.
2. Standing on the balance board with eyes closed.
3. Shaking the head while walking back and forth on the soft surface (e.g. cushion, mat) with gaze fixation (Rotates the head side to side horizontally with gaze fixed on a stationary target. Side-to-side head movement of w60 at a speed of 90/s, 1.5hz).
4. Shaking the head while standing on a soft surface (e.g. cushion, mat) with eyes closed.
5. Shaking the head while sitting on a pilates ball on a soft surface (e.g. cushion, mat) with eyes closed.

Table 2. Conventional vestibular exercises combined with table tennis exercises program

EXERCISE PROGRAM 1 (1-2.week)
1. Walking back and forth on the soft surface (e.g. cushion, mat) with eyes closed.
2. Standing on a firm surface on a one leg.
3. Standing on a cushion, with eyes closed, and sitting down standing up continuously.
4. Shaking the head while standing on firm surface, (Rotates the head side to side horizontally with gaze fixed on a stationary target. Side-to-side head movement of w60at a speed of 90/s, 1.5 hz).
5. Table tennis ball bounce with table tennis racket.
EXERCISE PROGRAM 2 (3-4. week)
1. March in place with eyes closed.
2. Standing on the balance board with eyes open.
3. Shaking the head while standing on the soft surface (e.g. cushion, mat) with eyes closed.
4. Standing on the mat with one leg with hands on waist and eyes closed.
5. Playing table tennis between a table and a wall (see picture).
6. Controlling the ball on the racket and walking without bouncing it.
EXERCISE PROGRAM 3 (5-6. week)
1. Walking to the right and left with sharp or wide turns with eye closed.
2. Standing on the balance board with eyes closed.
3. Shaking the head horizontally with gaze fixation on a stationary target while walking back and forth on the soft surface (e.g. cushion, mat) (Side-to-side head movement of w60 at a speed of 90/s, 1.5hz).
4. Shaking the head while standing on a soft surface (e.g. cushion, mat) with eyes closed.
5. Bouncing the ball between the racket and the table (see the picture). 6. Bouncing a ball with a racket against the wall (without using the table) (see the picture).

balance are shown. Participants must compensate for these sensory discrepancies and maintain their balance. Each person completed the tests as shown in Figure 3.

A balance score is obtained based on staying within 8.5 degrees in the anterior direction and 4 degrees in the posterior direction, as previously determined on the SOT and measured by the automatic device. Less postural sway indicates better postural stability in the sagittal plane and produces a proportional balance score, where a greater score indicates better balance. If the participant falls, or obtains a negative value by swaying beyond 12.5 degrees, they receive 0 balance points for that trial. More difficult conditions (3-6) receive larger weights, and an overall composite (COM) balance score uses a weighted average of all scores. A higher COM score indicates better postural control. Specific sensory systems are identified using ratio combinations of the average balance scores for each condition. Postural strategy scores are determined between 0 and 100, with 0 indicating the usage of only hip strategy, while 100 indicates the usage of sole ankle strategy. The better one maintains balance (i.e., the less sway), the more the ankle is used.

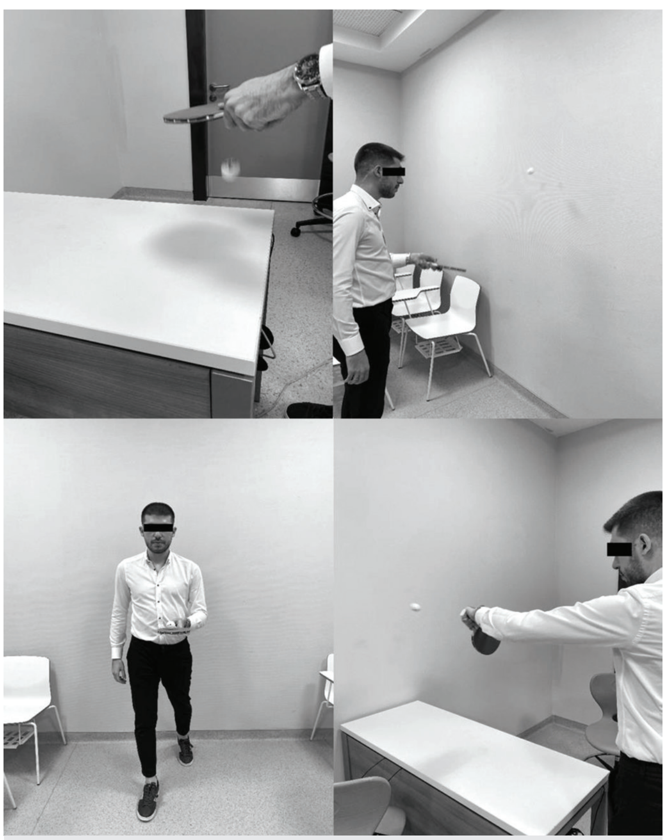

Figure 2. Table tennis exercises samples. A) Bouncing the ball between the racket and the table (CVE-TT/3rd Exercise Program/5th exercise). B) bouncing a ball with a racket against the wall (without using the table) (CVE-TT/3rd Exercise Program/6th exercise). C) Controlling the ball on the racket and walking without bouncing it (CVE-TT/2nd Exercise Program/6th exercise). D) Playing table tennis between a table and a wall (CVE-TT/2nd Exercise Program/5th exercise)

CVE-TT: Conventional vestibular exercises combined with table tennis

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics 22.0 program. The normal distribution of the values was assessed using the One-Sample Kolmogorov-Smirnov test. The descriptive statistics are reported as mean and standard deviation for normally distributed variables and median and interquartile range for non-normally distributed variables. A paired Student's t-test was used to determine whether there was a significant difference between the groups for normal distribution; otherwise, the Wilcoxon test was used. The significance value was taken as 0.05 (8). A randomized Two-Group Pretest-Posttest Design was performed. Mann-Whitney U test was performed to determine whether the pre-exercise values of the CVE group and CVE-TT group were similar. The Wilcoxon test was used to investigate whether there was a significant difference between the CVE and CVE-TT groups in pre- and post-study conditions.

RESULTS

In the CVE-TT, a statistically significant difference was found among Strategy 5, Strategy 6, COM, and VEST data scores pre and post, the study ($p<0.05$, $p<0.01$). No significant difference was found in Strategy 1, Strategy 2, Strategy 3, Strategy 4, somatosensorial (SOM), VIS, and VIS preference (PREF) data scores pre- and post-study ($p>0.05$) (Table 3) (Figure 4).

In the CVE, a statistically significant difference was found between Strategy 6 and PREF data scores before and after the study ($p<0.05$). No significant difference was found in Strategy 1, Strategy 2, Strategy 3, Strategy 4, Strategy 5, COM, SOM, VIS, and VEST data scores before and after the study ($p>0.05$) (Table 3).

Post-study results of CVE and CVE-TT were compared. A statistically significant difference was found between Strategy 4 scores of CVE and CVE-TT post-study ($p<0.05$). Although the post-study scores of CVE-TT were higher than those of CVE, no significant difference was found in the post-study Strategy 1, Strategy 2, Strategy 3, Strategy 5, Strategy 6, COM, SOM, VIS, PREF, and VEST scores of CVE and CVE-TT ($p>0.05$) (Table 3).

DISCUSSION

VEST, VIS, and somatosensory systems provide information to the central nervous system (CNS) to orient the body relative to itself and the external environment. This information is highly integrated into multiple CNS levels, allowing the system to modify the output based on the reliability of the input received (11). Preliminary research has demonstrated that VEST rehabilitation positively affects cognitive skills, especially for patients with central disorders (12). In the study of Schaefer and Scornaienchi (13), it was observed that playing table tennis for a long time provides cognitive benefits. Because of these results, we thought that table tennis might also be cognitively beneficial in VEST rehabilitation. The increase in COM data in our study may be associated with this hypothesis.

Table 3. Comparison between conventional vestibular exercises group and conventional vestibular exercises with table tennis exercises group of vestibular data and composite data in sensory organization test sensory analysis

Mean				p-value			
	CG Pre-exercise	CG Post-exercise	TG Pre-exercise	TG Post-exercise	Pairwise pre- and post-exercise of CG	Pairwise pre-and post-exercise of TG	Pairwise post-exercise of CG and TG
COM					0.340	0.004**	0.096
Mean±SD	78±3.74	79.50±4.74	77.80±5.89	84.28±5.41			
SOM					0.893	0.224	0.815
Median (IQR)	97 (1.91)	96 (2.32)	95 (3.40)	100 (3.40)			
VIS					0.917	0.204	0.102
Median (IQR)	71 (10.39)	86 (14.35)	80 (10.00)	93 (7.50)			
PREF					0.028*	0.821	0.710
Median (IQR)	93 (6.90)	100 (6.52)	94 (10.85)	98 (11.40)			
VEST					0.249	0.003**	0.066
Mean±SD	68.79±9.14	72.06±8.39	70.68±9.37	81.45±8.63			
Strategy I					0.705	0.113	0.182
Median (IQR)	93 (3.00)	92 (3.12)	91 (3.10)	97 (1.00)			
Strategy II					0.140	0.968	0.053
Median (IQR)	93 (2.50)	90 (2.60)	93 (2.50)	98 (2.10)			
Strategy III					0.892	0.588	0.349
Median (IQR)	93 (4.25)	91 (2.75)	90 (2.95)	95 (2.55)			
Strategy IV					0.104	0.465	0.046*
Median (IQR)	89 (2.37)	85 (6.05)	87 (5.60)	94 (4.10)			
Strategy V					0.893	0.023*	0.085
Median (IQR)	77 (12.62)	79 (10.82)	77 (8.80)	85 (7.70)			
Strategy VI					0.028*	0.008**	0.540
Median (IQR)	78 (9.00)	84 (7.80)	77 (8.75)	88 (8.80)			

*p<0.05; **p<0.01, CG: Conventional vestibular exercises group, COM: Composite data, IQR: Interquartile range, PREF: Preference data, SD: Standard deviation, SOM: Somatosensorial data, TG: Conventional vestibular exercises combined with table tennis group, VEST: Vestibular data, VIS: Visual data

In the 1940s, Cawthorne-Cooksey's early studies in VEST rehabilitation revealed that physical exercise positively affected balance function. However, the repetition of the study and the patients' boredom during these studies led the academicians to develop various exercises. We thought that table tennis exercises, which can be done comfortably at home, were fun and cost-effective solutions. It has been thought that table tennis is a beneficial sport for balance mainly because it requires a quick response to sudden actions and rapid eye movements for tracking the ball, which redirects focus from maintaining balance. Thus increasing the effectiveness of the VEST system in maintaining balance.

In this study, there was an increase in VEST function due to our use of CVE combined with table tennis. Our main goal is to design CVE combined with table tennis for those whose balance did not develop sufficiently only with VEST rehabilitation exercises. In addition to the development of the VEST system, the increase in the results of the SOT strategy score for the fifth and sixth conditions indicates that the person uses the ankle strategy better while balancing, and has been effective in decreasing the oscillation of the person. This shows when VEST exercises are used in combination with table tennis, it is associated with less oscillation as the VEST system develops in difficult balance conditions.

While there was a significant difference in VEST and COM values of SOT in the study group, COM and VEST values increased in the group where only VEST exercises were performed, but this increase was not statistically significant. This shows that CVE and table tennis significantly improve the function of the VEST system and posture control. In the CVE group, the increase in Preference data showed an increased dependence on the VIS system, indicating that in the absence of table tennis, trust in the VIS system becomes more prominent than trust in the VEST system.

There was a significant increase in PREF values in the CVE group in the pre-post comparison, and while there was a decrease in the CVE-TT group. The reason for this is that the PREF data relies on eye information. In other words, in line with the CVE-TT exercises we performed, we increased confidence in the VEST system and decreased eye dependence.

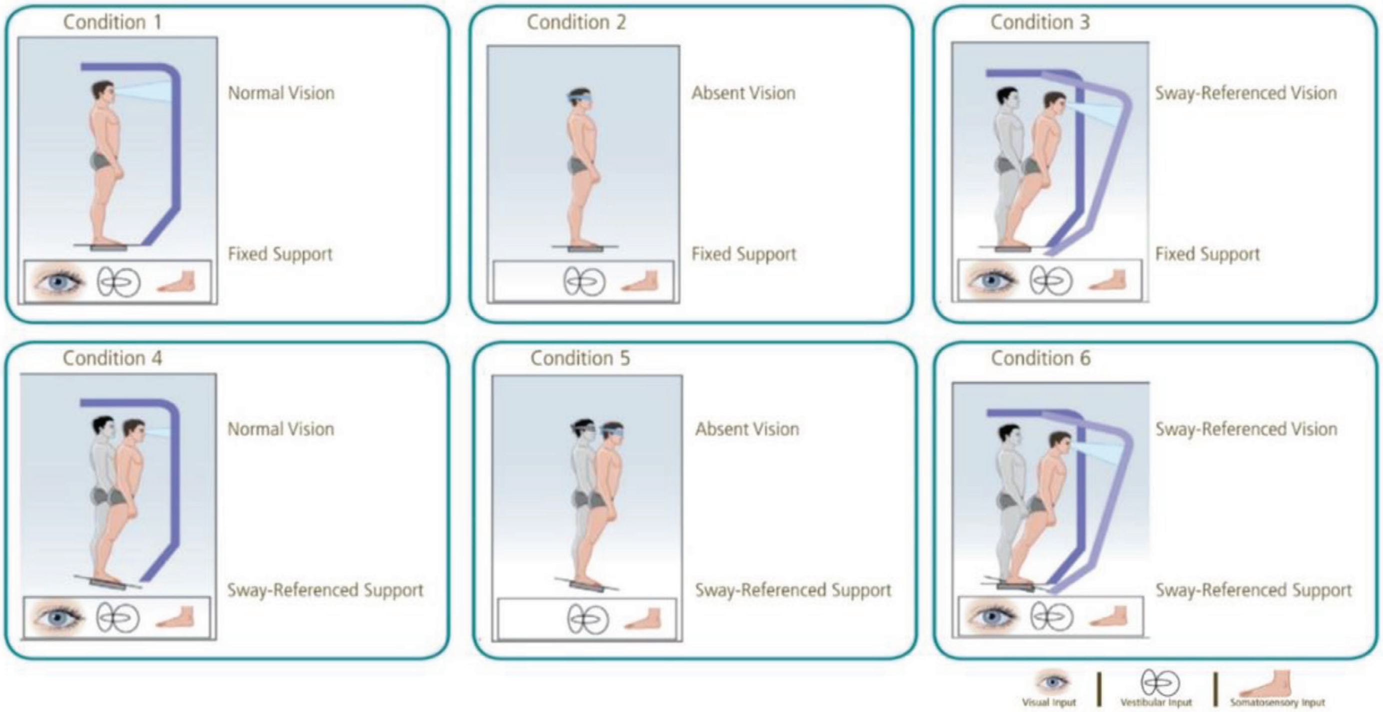

Figure 3. Sensory organization test conditions

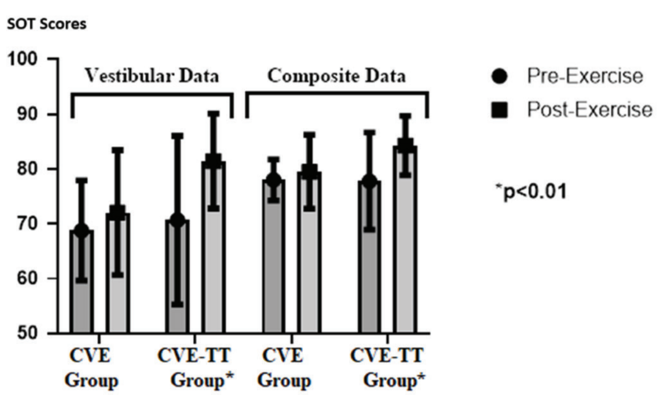

Figure 4. Comparison between CVE group and CVE-TT group of vestibular data and composite data in sensory organization test sensory analysis

CVE-TT: Conventional vestibular exercises combined with table tennis

Tekin Dal et al. (14) compared the effects of an activity-based home program and of Cawthorne-Cooksey exercises in 75 patients aged 18-65-years-old with chronic unilateral peripheral VEST disorders. They found a statistically significant improvement in Strategy 5, Strategy 6, and COM data scores in the activity group compared to the exercise group (15). In our study, we found a statistically significant difference between pre- and post-study, Strategy 5-6, COM, and VEST data scores in the CVE-TT group. Although the two studies have both similarities and differences, the advantages of activity-based programs that can be applied at home have emerged. In our study, unlike in the study of Tekin Dal et al. (14), table tennis was applied as the main component of the program.

In their study on adolescents, Christensen et al. (8) showed that a 6-week VEST exercise program improved VEST function. While the VEST data improved significantly in the group conventional VEST exercise programs combined with table tennis were applied, the difference was not statistically significant in the group where only CVE were applied, and this has shown that table tennis exercises can be a helpful method for the development of individuals' VEST systems.

Rogge et al.'s (15) study, shows that balance training leads to neuroplasticity in brain regions associated with VIS and VEST self-motion perception. These regions (especially the hippocampus) are known for their role in spatial orientation and memory. Therefore, stimulating VIS-VEST pathways during self-movement can mediate the beneficial effects of physical exercise on cognition (15). Therefore, since table tennis and balance exercises stimulate VEST-VIS pathways, the patient's balance is expected to benefit from this interaction. Elite expert table tennis players show stronger cortico-cortical communication between right-temporal and premotor areas than amateurs (16). In addition to these findings on coincidence anticipation performance, visuomotor reaction experiments revealed faster reaction times for table tennis players compared to both non-athletes and experienced tennis players (6). These results prove that table tennis activates different structures in the brain and enhances a person's balance, with effects dependent on mobility. This situation supports the increase in our study's COM general balance score.

Öztürk et al. (17) evaluated individuals with vestibular evoked myogenic potentials (VEMP) and Video Head Impulse tests in the presence of VIS illusions. According to this study, an increase was observed in the VEMP amplitudes of the individuals when the VIS illusion was given, and significant increases were observed in the gains of some semicircular canals. This showed that the VEST system works more efficiently with the stimulation of the VIS system. Consistent with this study, the better output of VEST data can be explained by the inclusion of a sport such as table tennis, where VIS attention is critical in VEST rehabilitation (17).

Study Limitations

There are several limitations in this study. In this study, young adults were included. These individuals were university students. However, considering that BPPV is more common in middle and older age groups, healthy individuals in this age group could have been included.

This is a preliminary study. Thus, instead of testing a study of unknown effects on patients, we first tested it on healthy subjects to observe improvement even in those whose data were within normal limits. The use of healthy subjects may not be a weakness for this study, but these results may not be reflective of a sample of people with persistent postural perceptual dizziness (PPPD) or residual dizziness (RD). Therefore, its application to these patient groups is recommended for further studies.

CONCLUSION

As a result, it has been shown that table tennis exercises, which are not difficult to implement, are low cost, can be played alone (against the wall or table), and will be more beneficial for general balance and VEST system development than conventional methods. This method assumes that people who do not have a pathological condition in objective tests but still feel unbalanced (dizzy) can also develop symptoms or conditions related to their perceived imbalance. Especially during this period, a rehabilitation program that can be implemented at home will be more efficient, amusing, and risk-free for individuals with balance problems, compared to going to the clinic. We think that the rehabilitation program will be a healthy option for individuals with subjective balance problems. This approach may objectively benefit patients with subjective dizziness, including those with PPPD or RD, for further research.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Non-Invasive Clinical Research Ethics Committee of Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee Presidency University with the decision no: 380, date: 27.06.2018.

Informed Consent: The study was explained to each participant, and written informed consent was obtained.

Footnotes

Author Contributions: Concept – K.E.; Design – K.E., C.Y., M.B.Ş.; Data Collection and/or Processing – K.E., C.Y., Analysis and/or Interpretation - K.E., C.Y., S. E., M.B.Ş.; Literature Search – K.E., C.Y., S. E., M.B.Ş.; Writing – K.E., C.Y., S. E., M.B.Ş.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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