Investigation of body weight distribution and ocular convergence in children practising table tennis

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Abstract

Background: Table tennis can be classified as a low-injury sport; however, it is associated with the frequent adoption of a forced playing position. Players are at significant risk of developing lateral spinal curvatures and asymmetries. A review of the scientific literature showed a variety of findings on the relationship between temporomandibular joints and posture.

Aims: This study aimed to investigate the relationship between temporomandibular joint (TMJ) dysfunction, lower limb loading and ocular convergence in table tennis players between 8 and 15 years old.

Material and methods: The study material consisted of the results obtained from 45 children between 8 and 15 years old. Players attending table tennis sports clubs were included in the study. The research group consisted of 18 girls (40%) and 27 boys (60%). A two-weights test was used to assess lower limb loading. In addition, visual system abnormalities were examined by measuring the near point of convergence. Two trials were used for each athlete before and after transient repositioning of the temporomandibular joints.

Results: Statistical analysis showed a significant association between temporomandibular joint position change and ocular convergence. There was no statistically significant association between lower limb loading and change in TMJ position. The relationship between lower limb loading and ocular convergence, athlete's training seniority, and received orthodontic treatment was also not supported.

Conclusion: A transient repositioning of the TMJ affected the trial of ocular convergence in the studied group. There was no correlation between TMJ changes and other measured parameters among examined tennis players.

Key words

temporomandibular joints, table tennis, ocular convergence, tandem balance test, two-weights test.

Introduction

The normal functioning of the human body is closely related to physical activity. However, in recent years, there has been a significant proliferation of sedentary lifestyle. It is somewhat related to the progress of civilization. Decreased exercise, known as hypokinesia, predisposes to increased incidence of many lifestyle diseases. Decreased levels of physical activity are increasingly observed in children and adolescents. This phenomenon is detrimental because children from 7 to 10/12 years of age are at the so-called second apogee of motor skills. This is a time when children have an increased need for physical activity. Therefore, it is very important to encourage a passion for physical activity and sport in the early years [1,2].

Table tennis is one of the most popular sports in the world. According to the International Sports Federation report, the number of players worldwide has reached more than 300 million. There are 15,000 people registered with the Polish Table Tennis Federation. It is a common form of physical activity as it can be used in physical education and recreation and is a therapeutic measure in many disease entities [3,4]. Furthermore, the sport is not restricted by age, demonstrated by a large number of young athletes and popular veteran competitions [3,4].

Regular physical activity helps to improve a psychological well-being and prevents the development of many diseases. However, despite the many benefits of exercise, it is important to note that there can also be adverse effects. They mainly affect the skeletal system and are most severe in athletes [5]. Systematic and lengthy training combined with intense, asymmetrical bodywork can lead to overload. These can result in musculoskeletal injuries and deformities. Large, often unilateral loads can also affect posture and symmetry [4].

Table tennis can be classified as a low-injury sport. However, long-term practice of the sport started in the early years of life is associated with frequent adoption of a forced playing position. It is characterized by asymmetrical body positioning and loading. The athlete assumes a straddle position where the lower extremity is bent at the knee joint. Thus, more stress is placed on one side of the body. Bone growth, a period in which posture is largely formed, has not yet been completed in early childhood athletes. As a result, these players are at significant risk of developing lateral spinal curvatures and asymmetries [5].

Aims

The purpose of this study was to investigate the relationship between temporomandibular joint (TMJ) dysfunction, lower limb loading, and ocular convergence in table tennis players between 8 and 15 years old.

Material and methods

The research material consisted of 45 children between 8 and 15 years old [6]. The study investigated players attending table tennis classes of selected sports clubs operating in Silesian Voivodeship in Poland. The study was conducted between July 2019 and January 2020. The characteristics of the study group are shown in **Table 1**.

The examined children were healthy and evaluated by a sports doctor. Among the subjects, 18 were children undergoing orthodontic treatment. The respondents mainly were right-handed (84%). The inclusion criteria were: age between 8 and 15 years, belonging to one of the sports clubs, active and regular participation in table tennis training, and consent of parents or legal guardians to conduct the study. Exclusion criteria were: age other than 8-15, non-participation in a sports club, musculoskeletal conditions affecting posture and postural stability, other medical conditions.

The testing of the athletes consisted of several steps. The first condition to qualify a player was the consent and signing of documents by parents or legal guardians of children belonging to one of the table tennis clubs. Then the parent, together with the examined child, was asked to fill in the proprietary survey questionnaire, which allowed for the characterization of the studied children **(Table 1)**.

Table 1. Characteristics of the study group [6].

	Age (years)		**Bodyweight** (kg)		**Body height** (cm)		**Training experience** (years)	
Sex	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Girls (n=18)	11.7	1.76	42.6	13.89	151.5	11.73	4.1	1.69
Boys (n=27)	12.6	1.97	47.5	14.43	159.6	15.56	4.7	1.68
M – mean; **SD** – standard deviation								

Physical examinations were held in the gymnasium and the club's auditorium. The rooms were spacious, well lit, and at room temperature. Two test sites were prepared prior to the start of the study. At station one, which measured 2x2m, two analogue scales were set up 5cm apart, a centimetre tape measure, a table on which the authors' printed study cards, pens, disinfectant, paper towel, disposable gloves, and disposable rollers were laid out. A second station of the same dimensions was set up with a table on which the author's printed test card, an ocular convergence measuring device, disposable gloves, and disposable rollers were placed. In addition, an "X" was taped on the floor 1.5m from the solid-coloured wall to designate the player's placement.

The study began at station 1 with measuring the child's height and weight. The child then removed their shoes and stepped on the scales. Each foot was to be placed in the middle of a separate scale. Next, the child was asked to maintain an upright posture. In this position, a weight reading was taken from each scale. Once the measurements were taken, the child was given two disposable rollers (0.5 x 1.0 x 5.0 cm) to place between the upper and lower premolars and molars. The task was to firmly clench the rollers for 10 seconds while maintaining an upright posture on the scales. The examiner read the values shown on the scales and entered them into the test card during this time.

In the next stage of the study, ocular convergence was measured at a second station. The child under examination positioned themselves in comfortable footwear, in a posture position on a marked spot, facing a solid-coloured wall. Measurements were taken with a solid colour pencil ending with a 1.5 x 1.5 cm tip of a different colour. The participant was asked to follow the coloured tip with their eyes. The measurement was initiated at a distance of approximately 15cm from the tip of the subject's nose. Then, with a steady motion in the sagittal plane, the tip of the pencil was brought closer in the subject's line of sight. Close-ups were performed until convergent ocular movement was observed or a distance of 3 cm was reached from the tip of the nose. The duration of the measurement was 5 seconds. The instrument was then moved away in a steady motion. Before starting the second trial, the child was given two 0.5 x 1.0 x 5.0 cm rollers and, as in the test on station one, was asked to clench them between the teeth. After ten seconds of clenching, the child was asked to relax the grip, and the measurement was repeated. The observed findings were recorded in the patient's examination chart.

Calculations were performed through the R 3.6.0 statistical environment, PSPP software, and MS Office 2019. The obtained quantitative data underwent statistical analysis using the following: chi-square test for variables expressed at an ordinal or nominal level. A continuity correction was used for 2x2 tables, and when the conditions for using the chi-square test were not met, Fisher's exact test with expansion for tables larger than 2x2 was used. In addition, parametric tests such as the Student's t-test or their non-parametric equivalent such as the Mann-Whitney U test were used to analyze quantitative variables presented by the group. The choice of tests was based on the distribution of variables, which was verified by the Shapiro-Wilk test. The level of statistical significance was assumed to be $p = 0.05$.

Results

The detailed results of the two-weights test measurement are presented in **Table 2**. When measuring with the two-weights test, the correct result was an even bodyweight distribution on both scales. The final test result was the difference in the values read from the scales. No statistically significant differences ($p > 0.05$) were found between measurements on the two-weights test.

Decreases in the two-weights test values were noted in 17 individuals (negative ranks), and increases were noted in 13 subjects (positive ranks). Equal values (bindings) appeared 15 times. In the first measurement, the median of the two-weights test was *Me* = 2.00. In the second measurement, the median was also *Me* = 2.00. This means that half the people scored no less than 2.00, and half scored no more than 2.00. Thus, the two-weights test showed minimal variability between measurements and no statistically significant differences ($p > 0.05$).

Table 2. First and second trial results for the two-weights test [6].

Descriptive statistics	M	SD	Min	Max	Q25	Me	Q75
Two-weights test - trial 1	2.22	1.69	0.00	7.00	1.00	2.00	3.00
Two-weights test - trial 2	2.02	1.83	0.00	6.00	1.00	2.00	3.00
M – mean; **SD** – standard deviation; **Min** – minimum; **Max** – maximum; **Q25** – first quartile; **Me** – median; **Q75** – third quartile							

It was hypothesized that orthodontic treatment would significantly differentiate the two-weights test. Therefore, after inspecting the assumptions of normality of distribution, it was reasonable to use the non-parametric Mann-Whitney U-test.

In the two-weights test - in the first attempt, half of the orthodontically treated subjects obtained no less than *Me* = 2.00. The minimum score within the group was *Min* = 1.00, while the maximum score was *Max* = 7.00. Half of the non-orthodontically treated subjects scored no less than *Me* = 1.00. The minimum score was *Min* = 0.00, while the maximum score was *Max* = 5.00. The results in both groups were similar. The differences reported above are not statistically significant ($p > 0.05$).

Table 3. The Wilcoxon matched-pair test - the two-weights test [6].

Wilcoxon test	W	p	Min	Max	Me
Two-weights test	261.00	0.554			
Two-weights test - trial 1			0.00	7.00	2.00
Two-weights test - trial 2			0.00	6.00	2.00
W – test statistic; **p** – statistical significance; **Min** – minimum; **Max** – maximum; **Me** – median					

In the two-weights test - second attempt, half of the orthodontically treated subjects scored no less than *Me* = 1.00. The minimum score was *Min* = 0.00, while the maximum score was *Max* = 6.00. Half of the non-orthodontically treated subjects scored no less than *Me* = 2.00. The minimum score within the group was *Min* = 0.00, while the maximum score was *Max* = 6.00. The differences presented above were not statistically significant ($p > 0.05$).

Table 4. The Mann-Whitney U test for independent samples: orthodontic treatment - the two-weights test [6].

Mann-Whitney U test		U	p	Min	Max	Me
Two-weights test - trial 1		185.0	0.167			
Orthodontic treatment	yes			1.00	7.00	2.00
	no			0.00	5.00	1.00
Two-weights test - trial 2		238.0	0.915			
Orthodontic treatment	yes			0.00	6.00	1.00
	no			0.00	6.00	2.00
U – test statistic; **p** – statistical significance; **Min** – minimum; **Max** – maximum; **Me** – median						

The results in both groups were similar in the first and second measurements. However, the differences were not found statistically significant, and thus the assumption made was not confirmed.

Years of training were found to differentiate the two-weights test significantly. Therefore, two categories within the variable showing years of training were created for the analysis. This was necessary for further analysis. After checking the assumptions of normality of distribution, it was reasonable to use the non-parametric Mann--Whitney U-test.

In the two-weights test - in the first attempt, half of the group training up to 5 years scored no less than *Me* = 2.00. The minimum score among the group was *Min* = 0.00, while the maximum score was *Max* = 7.00. Half of the group training five years or more scored no less than *Me* = 1.50. The minimum score was *Min* = 0.00, while the maximum score was *Max* = 6.00. The results were similar. The differences reported above were not statistically significant ($p > 0.05$).

Table 5. The Mann-Whitney U test for independent samples: years of training - two-weights test.

Mann-Whitney U test		U	p	Min	Max	Me
Two-weights test - trial 1		246.0	0.897			
Years of training	up to 5 years			0.00	7.00	2.00
	over 5 years			0.00	6.00	1.50
Two-weights test - trial 2		248.0	0.935			
Years of training	up to 5 years			0.00	5.00	2.00
	over 5 years			0.00	6.00	1.00
U – test statistic; **p** – statistical significance; **Min** – minimum; **Max** – maximum; **Me** – median						

On the other hand, in the two-weights test - second attempt, half of the group training up to 5 years scored no less than *Me* = 2.00. The minimum score within the group was *Min* = 0.00, while the maximum score was *Max* = 5.00. Half of the group training for more than five years scored no less than *Me* = 1.00. The minimum score was *Min* = 0.00, while the maximum score was *Max* = 6.00. The differences reported above were not statistically significant ($p > 0.05$). The results were also similar. Therefore, this assumption has also not been confirmed. The detailed results of the ocular convergence measurement are presented in **Table 6**.

Table 6. First and second trial results for the ocular convergence measurement [6].

Two-weights test - trial 1	**Frequency** (N)	**Percent** (%)
Normal	17	37.80
Disturbed	28	62.20
Two-weights test - trial 2	**Frequency** (N)	**Percent** (%)
Normal	34	75.60
Disturbed	11	24.40

Due to the nature of the study, the values were changed to quantitative values. A correct score was reported as 1, and dysfunction was reported as 0. Thereby, two measurements were compared. There were statistically significant differences between ocular convergence measurements ($p < 0.05$).

Reduction in normal ocular convergence was reported in 2 cases (negative ranks), and the increase was reported in 19 cases (positive ranks). Equal values (bindings) occurred 24 times. In the first measurement, the median ocular convergence was *Me* = 0.00, whereas, in the second measurement, the median was *Me* = 1.00. This means that half of the people scored less than 0.00, while in measure two, half of the people scored more than 1.00. These differences were statistically significant ($p < 0.05$). Significant variations between ocular convergence measurements were found based on the analysis. There was a significant increase in the parameter value, resulting in an increase in correct scores among those with the dysfunction compared to the first measurement. It was hypothesized that orthodontic treatment significantly differentiates the ocular convergence test results. Verification of the presence of a relationship was performed using the chi-square test.

Regarding ocular convergence - the first trial among orthodontically treated subjects - correct results were reported in 22.2% and among untreated subjects in 48.1%. The obtained test results ($p > 0.05$) were not statistically significant. There was no significant relationship ($p > 0.05$) between orthodontic treatment and the first trial of ocular convergence in the examined group. It can only be mentioned that fewer people reached normal results among those who were treated. The differences were not statistically significant.

Table 7. The Wilcoxon matched-pair test - the ocular convergence [6].

Wilcoxon test	W	p	Min	Max	Me
Two-weights test	22.00	**< 0.001**			
Two-weights test - trial 1			0.00	1.00	0.00
Two-weights test - trial 2			0.00	1.00	1.00
W – test statistic; **p** – statistical significance; **Min** – minimum; **Max** – maximum; **Me** – median					

Correct values were recorded in the second measurement in 77.8% of the orthodontically treated subjects and 74.1% of the non-orthodontically treated subjects. The obtained test result ($p > 0.05$) was statistically insignificant. There was no significant relationship ($p > 0.05$) between orthodontic treatment and the second ocular convergence measurement in the examined group. In both the first and second cases, the assumption was not confirmed. Years of training were also assumed to differentiate the ocular convergence test results significantly. Verification of the presence of a relationship was performed using the chi-square test.

Table 8. Results of the χ^2 test: orthodontic treatment - the ocular convergence [6].

Orthodontic treatment					Test results
			Yes	No	
Two-weights test - trial 1	Normal	N	4	13	$\chi^2 = 2.084$
		%	22.2%	48.1%	$df = 1$
					$p = 0.149$
	Disturbed	N	14	14	
		%	77.8%	51.9%	
Two-weights test - trial 2	Normal	N	14	20	$\chi^2 = 0.000$
		%	77.8%	74.1%	$df = 1$
					$p = 1.000$
	Disturbed	N	4	7	
		%	22.2%	25.9%	
χ^2 – test statistic; df – degrees of freedom; p – statistical significance					

Regarding ocular convergence - the first trial among the individuals training up to 5 years – correct results were reported in 37.5% and among the subjects training more than five years in 38.1%. The obtained test results ($p > 0.05$) were not statistically significant. There was no significant relationship ($p > 0.05$) between years of training and the first trial of ocular convergence in the examined group.

In the second trial, among the group of athletes training up to 5 years, the correct results were noted in 79.2% and among the group training 5 years and more - in 71.4%. There was no significant relationship ($p > 0.05$) between years of training and the second ocular convergence trial in the tested group. The obtained results were close to each other; therefore, the assumption was not confirmed.

Table 9. Results of the χ^2 test: years of training - the ocular convergence [6].

Years of training					**Test results**
			up to 5 years	over 5 years	
Two-weights test - trial 1	Normal	N	9	9	$\chi^2 = 0.000$
		%	37.5%	38.1%	$df = 1$
					$p = 1.000$
	Disturbed	N	15	13	
		%	62.5%	61.9%	
Two-weights test - trial 2	Normal	N	19	15	$\chi^2 = 0.065$
		%	79.2%	71.4%	$df = 1$
					$p = 0.799$
	Disturbed	N	5	6	
		%	20.8%	28.6%	
χ^2 – test statistic; ***df*** – degrees of freedom; ***p*** – statistical significance					

It was also assumed that ocular convergence would significantly affect the outcome of the two-weights test. Therefore, the non-parametric Mann-Whitney U test was used after checking whether the distribution was normal. This is a test that compares the medians of the dependent variable across groups. The test of the relationship between ocular convergence and the score obtained in the two-weights test on the first trial was presented in **Table 10**.

Table 10. The Mann-Whitney U test for independent samples: convergence of eyes (first trial) - the two-weights test (first trial) [6].

Mann-Whitney U test		**U**	**p**	**Min**	**Max**	**Me**
Two-weights test - trial 1		235.50	0.961			
Two-weights test - trial 1	Normal			0.00	4.00	2.00
	Disturbed			0.00	7.00	1.00
U – test statistic; **p** – statistical significance; **Min** – minimum; **Max** – maximum; **Me** – median						

Half of the group with normal ocular convergence results scored no less than *Me* = 2.00. The minimum score among the group was *Min* = 0.00, while the maximum score was *Max* = 4.00. Half of the group with impaired performance scored no less than *Me* = 1.00. The minimum score was *Min* = 0.00, while the maximum score was *Max* = 7.00. The differences indicated above were not statistically significant ($p > 0.05$).

After assessing the normality of the distribution, it was appropriate to use the non-parametric Mann-Whitney U test. Table 10 shows the test of the relationship between convergence dysfunction and weight distribution after applying transient TMJ repositioning.

Half of the group with normal ocular convergence results scored no less than *Me* = 2.00. The minimum score among the group was *Min* = 0.00, while the maximum score was *Max* = 6.00. Half of the group with impaired performance scored no less than *Me* = 1.00. The minimum score was *Min* = 0.00, while the maximum score was *Max* = 3.00. Despite differences between normal and dysfunctional results, the hypothesis cannot be confirmed. The differences were not statistically significant. Based on the analysis, it was observed that individuals with impaired convergence performed better on the two-weights test in the study group. The differences indicated above were not statistically significant ($p > 0.05$).

Table 11. The Mann-Whitney U test for independent samples: eyes convergence (second trial) - two-weights test (second trial) [6].

Mann-Whitney U test		U	p	Min	Max	Me
Two-weights test - trial 2		138.00	0.192			
Two-weights test - trial 2	Normal			0.00	6.00	2.00
	Disturbed			0.00	3.00	1.00
U – test statistic; **p** – statistical significance; **Min** – minimum; **Max** – maximum; **Me** – median						

Discussion

Scientific research confirms the existence of nerve connections between the temporomandibular joints, the visual organ, and the muscles responsible for maintaining proper posture. It has been examined that temporomandibular joint misalignment can cause problems with body balance while standing and adversely affect visual function [7-9].

A review of the scientific literature showed a variety of findings on the relationship between temporomandibular joints and posture. A literature review conducted by Cuccia and Caradonna [10] showed a correlation between the stomatognathic system and posture. Patients with TMJ abnormalities showed more significant deviation in the vertical projection of the centre of gravity. Several studies showed that subjects with stomatognathic dysfunctions presented excessive head protraction and increased cervical lordosis due to shortening of the posterior group of neck muscles and the sternocleidomastoid muscle. Moving your head forward also reduces your field of vision. The body compensates for this restriction by increasing lordosis in the cervical region. Moving the head forward also disrupts the position of the centre of gravity, confirming that there is a relationship between the temporomandibular joints and posture. Incorrect positioning and biomechanics of the cervical region can lead to pathological positioning of the mandible, resulting in dysfunction within the stomatognathic system. However, due to many factors affecting the TMJ joint, existing studies are insufficient to state all associations conclusively [10].

In the present study, 32 children had an improved or unchanged weight distribution difference in the second trial compared to the first trial during the two-weights test. In 13 children, the weight distribution in trial two was less equal than in trial one - it worsened. In 14 children, the difference in load after roller biting was performed did not change. However, our study did not show that the applied transitional temporomandibular joint position modification affected lower limb loading in the examined group. The difference between the first and second trials was not statistically significant.

When analyzing the results, it is important to consider that the researched group consisted of healthy children and adolescents during the growth period. Thus, abnormalities of anterior or posterior anatomical band tension in the body, causing abnormal weight distribution, are not yet established. It is possible that for this reason, the occurrence of a relationship between TMJ joints and posture has not been observed. However, it should be noted that some subjects (27%) had improved stabilization after transient temporomandibular joint repositioning. Furthermore, during the second trial reading from the scale, the child stood still, in contrast to the first reading, during which the child had difficulty staying upright and was balancing. It should also be noted that it is worthwhile to conduct such studies in the future on more objective tools, such as stabilometric platforms.

Monaco et al. [11] reported a relationship between visual impairments, malocclusion, and dysfunction in temporomandibular joints. They described those visual defects are more common in patients with Class II malocclusions than in Class I and Class III malocclusions. In addition, their research indicated that children with visual impairments showed an increase in temporal muscle tension at rest during changes in stomatognathic muscle tone, which was not observed in healthy children [117].

In our study, the first trial of ocular convergence revealed its impairment in 28 subjects. After temporomandibular joint repositioning, convergence dysfunction was reported in only 11 subjects. The Wilcoxon paired t-test showed a statistically significant association ($p < 0.001$) between the trials. Statistical analysis showed that transient repositioning of the temporomandibular joint affected the ocular convergence performance during the second trial. 18 of the studied tennis players underwent orthodontic treatment. However, statistical analysis showed no significant relationship between the use of orthodontic treatment, the ocular convergence and two-weights test performance.

A scientific literature review found no papers examining a potential relationship between the presence of ocular convergence dysfunction and body weight distribution. Despite showing differences between subjects with normal convergence and abnormal convergence scores, the hypothesis cannot be confirmed in our study. The differences were not statistically significant. However, it was observed that in the examined group, individuals with convergence impairments performed better on the two-weights test. However, this may be due to the fact that during the second convergence trial, as many as 75% achieved a normal result, which disturbed the proportion of the study. It would be beneficial to continue the study with a larger number of participants.

The research conducted by Wojtkow et al. [5] showed a correlation between the length of training experience and a higher load on one lower limb in athletes practising asymmetrical sports. This relationship was argued to be the body's adaptation mechanism to frequent asymmetrical loading. The mean age of the players was 21, and the mean length of experience was 7.7 years [5].

However, our study did not show a relationship between years of competitive training, bodyweight distribution, and ocular convergence. It is important to keep in mind that the average age of the examined tennis players was 12 years old, and their training experience averaged 4.4 years. Thus, it is a much smaller developmental and professional experience for the body. It is possible that the results of adult tennis players with a longer playing career would be similar to those obtained by Wojtkow et al. [5].

Due to the limited number of studies on the occurrence of relationships between temporomandibular joints, posture, and vision, it would be recommended to investigate them further on a larger scale. In order to obtain more detailed results, it would be beneficial to use precise measurement methods. The use of stabilometric platforms would allow for the objectification of the study. Additionally, they should be augmented by comparing tennis players with non-players. This would allow for a comprehensive evaluation of the effect of table tennis training on the examined parameters in the study and control group.

Conclusion

A temporary change in the position of the temporomandibular joints did not affect the distribution of lower limb load in the study group, but it did affect ocular convergence in children practising table tennis. Ocular convergence disorders do not affect the weight distribution in the examined subjects. Years of competitive training have not been shown to affect the distribution of body weight and convergence among table tennis players. In addition, the use of orthodontic treatment had no significant effect on weight distribution and ocular convergence in the examined children.

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