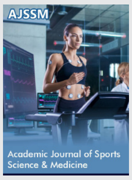

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Research Article

Effects of Occlusal Intervention on Sports Vision and Motor Function: Study in Trampoline Competitions

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Abstract

Purpose: The purpose of this study was to clarify the effect of occlusal intervention on the relationship between sports vision and jumping skills in trampoline gymnastics.

Method: Participants were 12 male trampoline gymnasts (17.8±2.1 years). Sports vision was evaluated by measuring three items: dynamic visual acuity in the forward/backward direction (DVA-FB), dynamic visual acuity in the left/right direction (DVA-LR), and eye-hand coordination (EHC). The measurement conditions were three: no occlusal intervention (NOI), chewing gum (CG), and wearing a mouthguard (MG). Jumping skills were assessed by two trials: 1) 10 consecutive straight jumps (SJ), and 2) 5 consecutive sets of one backflip followed by a barani (BJ). Each trial was performed under two conditions: with and without a mouthguard, and T-score was measured. The effects of occlusal intervention on each sports vision were analyzed using one-way analysis of variance with repeated measures or the Friedman test. In addition, the rate of change in sports vision score and T-score due to mouthguard wearing was calculated, and the correlation between the two was analyzed using Pearson's product-moment correlation coefficient or Spearman's rank correlation coefficient.

Results: In the order of NOI, CG, and MG, DVA-FB and DVA-LR showed high values, while EHC showed low values. A significant correlation between the rate of change in sports vision and jump score due to occlusal intervention was observed between DVA-FB in SJ and between DVA-FB, DVA-LR, and EHC in BJ ($P<0.05$).

Conclusion: The effects of occlusal intervention on the relationship between sports vision and jumping skills in trampoline competitions were examined, and it was found that occlusal intervention improved dynamic visual acuity and eye-hand coordination. Furthermore, the effect on jumping skills differed depending on the type of jump types, and it was suggested that performances involving rotations and twists were more closely related to sports vision.

Keywords: Trampoline competition; flight time; sports vision; dynamic visual acuity; eye-hand coordination; occlusion; mouthguard

Introduction

In many sports, athletes use their vision to understand the positional relationship between their surroundings and their body or targets, and control their movements based on this information [1]. In particular, for players to instantly and accurately grasp multiple pieces of information - the movements of other players, the movement of the ball, the position of the goal or target - and to select and execute the appropriate action, they must use their vision to grasp the ever-changing circumstances in the surrounding environment and determine priorities from multiple pieces of visual information. It has been reported that athletes at highly competitive levels have better sports vision, and that the sports environment during childhood has a significant influence on the visual development of these athletes [1].

Trampoline competitions are a sport in which 10 consecutive routines are scored based on four criteria: difficulty score (D-score), performance score (E-score), flight time score (T-score), and movement deduction score (H-score) [2,3]. These routines are executed while the gymnast is in the air, and landing preparation takes place in the latter half of the airborne period. Accordingly, the jump height enables the gymnast to attempt more difficult techniques and gives them more time to pursue the beauty of the performance [4,5]. In other words, to improve their D-score and E-score, gymnasts must ensure that they have sufficient flight time. The two main factors impacting flight time are the take-off action and the landing position. The center of the trampoline bed is marked with a red cross, and by landing there, the gymnast can efficiently use the bed's spring elasticity to bounce their body up vertically. The landing position is not only evaluated as the H-score but also reflected in the T-score because it affects the height of the next jump. Gymnasts must instantly recognize the position of the center of the bed and control their body movements while in the air, and thus the ability to control minute changes in posture and sports vision are key characteristics of trampoline competition [6]. In particular, because performances involving multiple rotations and twists require a large amount of forward, backward, and side-to-side movement of the center of gravity, which can easily cause the landing position to deviate from the center of the bed, precise posture control using vision is critical. Furthermore, the main sensory inputs responsible for human postural control are vision, vestibular sensation, and somatosensory sensation, and it has been suggested that changes in occlusion can affect the sensitivity of somatosensory input [7-9].

The purpose of this study was to clarify the effect of occlusal intervention on the relationship between sports vision and jumping skills in trampoline gymnastics. The null hypothesis was that the relationship between sports vision and jumping skill in trampoline gymnastics would not be affected by occlusal intervention.

Materials and Methods

Ethical Approval and Informed Consent

This study was conducted with the approval of the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (approval no. ECNG-R-443). The study aims and procedures were fully explained to all participants, and written informed consent was obtained from all individuals prior to their participation.

Participants

The participants were 12 male high school and university students who belonged to the trampoline club (average age 17.8±2.1 years; average competitive experience 11.8±2.0 years). These students train 3 h per day, six days a week.

Fabrication of Custom Mouthguard

Mouthguards were fabricated for each gymnast, using a 2.0-mm-thick ethylene vinyl acetate thermoplastic elastomer (Sports Mouthguard; Keystone Industries, Cherry Hill, NJ) and a pressure molding machine (Model Capture Try; Shofu Inc., Kyoto, Japan). After being reshaped and polished by dentists, the mouthguards were placed in the participants' mouths and adjusted to ensure even contact between all teeth during light mouth closure [10-12]. The occlusal contact condition of the mouthguard was confirmed by occlusal examination using blue silicone (Bite Eye; GC Co., Tokyo, Japan), and adjustments were made so that the difference in occlusal contact area between the left and right sides was less than 10%. Gymnasts who experienced a strong foreign body sensation or discomfort when wearing a mouthguard were excluded from the study.

Sports Vision Measurement

Sports vision was evaluated by measuring three items: dynamic visual acuity in the forward/backward direction (DVA-FB), dynamic visual acuity in the left/right direction (DVA-LR), and eye–hand coordination (EHC). The three measurement conditions were no occlusal intervention (NOI), chewing gum (CG), and wearing a mouthguard (MG).

DVA-FB was measured using a dynamic visual acuity tester (AS-4A; Kowa Co. Ltd., Aichi, Japan) designed to correspond to a visual acuity value of 1.0 when the Landolt ring is positioned at a distance of 30 m. Participants were instructed to press a switch the moment they were able to identify the orientation of a Landolt ring traveling in a straight line from 50 m to 2 m in front of them at 30 km/h. If the answer was correct, the converted value was used as the measurement value [13-17].

DVA-LR was measured using a dynamic visual acuity monitor (HI-10; Kowa Co. Ltd.). The Landolt ring of the measuring device moves horizontally from left to right across a 90-degree hemispherical screen. Participants were asked to track the Landolt ring using only their eye movements as it gradually decelerated from 40 rpm/min, and to press a switch the moment they were able to identify the orientation of the Landolt ring. The speed at which the answer was correct was recorded.

EHC was measured using a coordination measurement device (Acu Vision-1000; Kowa Co. Ltd.), which consisted of a 300 × 130 cm panel with 120 touch sensors, each 3 cm in diameter. The sensor is designed to turn off when pressed while it is lit, and the 120 sensors are activated randomly during one measurement. The time it took for the 120th sensor to go off was recorded [16,17].

Jumping Skills Measurement

Trampoline gymnastics jumping skills were assessed by two trials: 1) 10 consecutive straight jumps, and 2) 5 consecutive sets of one backflip followed by a barani (i.e., a 1/2 turn to the side while performing a 1-turn forward somersault) (BJ). The HDTS (horizontal displacement, time-of-flight, synchronicity) trampoline measurement system (EU-7100; Eurotramp, Weilheim an der Teck, Germany) recorded the flight time of each jump from 1 to 10, the landing position (cm) in the front-to-back and left-to-right directions from the center of the bed, and the total flight time (T-score) and movement point (H-score) for 10 jumps [18-21]. In each trial, recording began after one preliminary jump. One trial consisted of 10 jumps, and was performed under two conditions: with and without a mouthguard. The T-score for each trial was used as the analysis item.

Statistical Analysis

Statistical analyses were performed using SPSS 17.0 software (SPSS Japan Inc., Tokyo, Japan). The significance level was set at $P<0.05$. Normality was analyzed using the Shapiro-Wilk test.

The sports vision measurement values were showed normality at all levels except for the MG condition of the DVA-LR. Because Mauchly's test of sphericity was not significant for the differences in DVA-FB or EHC due to occlusal intervention (i.e., homogeneity of variance was guaranteed), a one-way analysis of variance with repeated measures was performed, followed by a multiple comparison test among levels, using the Bonferroni method. The Friedman test was performed to check for differences in DVA-LR due to occlusal intervention, followed by a multiple comparison test among levels, using the Bonferroni method.

Next, the rate of change in MG compared with NOI was calculated for each sports vision score and the T-score for each trial. Normality was observed at all levels except for the rate of change in the straight jump's T-score. Therefore, correlation analysis was performed using Spearman's rank correlation coefficient to determine the correlation between the rate of change in each sports vision score and the straight jump's T-score. The correlation between the rate of change in each sports vision score and the barani jump's T-score was analyzed using Pearson's product-moment correlation coefficient.

Results

Figure 1 shows the effect of occlusal intervention on sports vision. DVA-FB showed higher values in the order of NOI, CG, and MG, and a significant difference was observed between NOI and MG ($P<0.01$). DVA-LR showed higher values in the order of NOI, CG, and MG, and significant differences were observed between NOI and CG as well as between NOI and MG ($P<0.01$). EHC showed lower values in the order of NOI, CG, and MG, and significant differences were observed between NOI and CG ($P<0.05$), between NOI and MG ($P<0.01$), and between CG and MG ($P < 0.05$).

Figure 2 shows the results of the correlation analysis between the rate of change in sports vision due to wearing a mouthguard and the rate of change in the straight jump's T-score. A significant positive correlation was found between the rate of change in DVA-FB and the rate of change in the T-score ($R = 0.585$, $P<0.05$). There was a tendency for the rate of change in the DVA-LR to be associated with a greater rate of change in the T-score, but no significant correlation was observed ($R = 0.238$). The greater the rate of change in EHC, the smaller the rate of change in the T-score tended to be, but no significant correlation was observed ($R = -0.273$).

Figure 3 shows the results of the correlation analysis between the rate of change in sports vision due to wearing a mouthguard and the rate of change in the barani jump's T-score. The greater the rate of change in DVA-FB, the greater the rate of change in the T-score, and a significant positive correlation was found between the two ($R = 0.676$, $P<0.05$). The greater the rate of change in DVA-LR, the greater the rate of change in the T-score, and a significant positive correlation was observed ($R = 0.665$, $P<0.05$). The greater the rate of change in EHC, the smaller the rate of change in T-score tended to be, and a significant negative correlation was observed ($R = -0.582$, $P<0.05$).

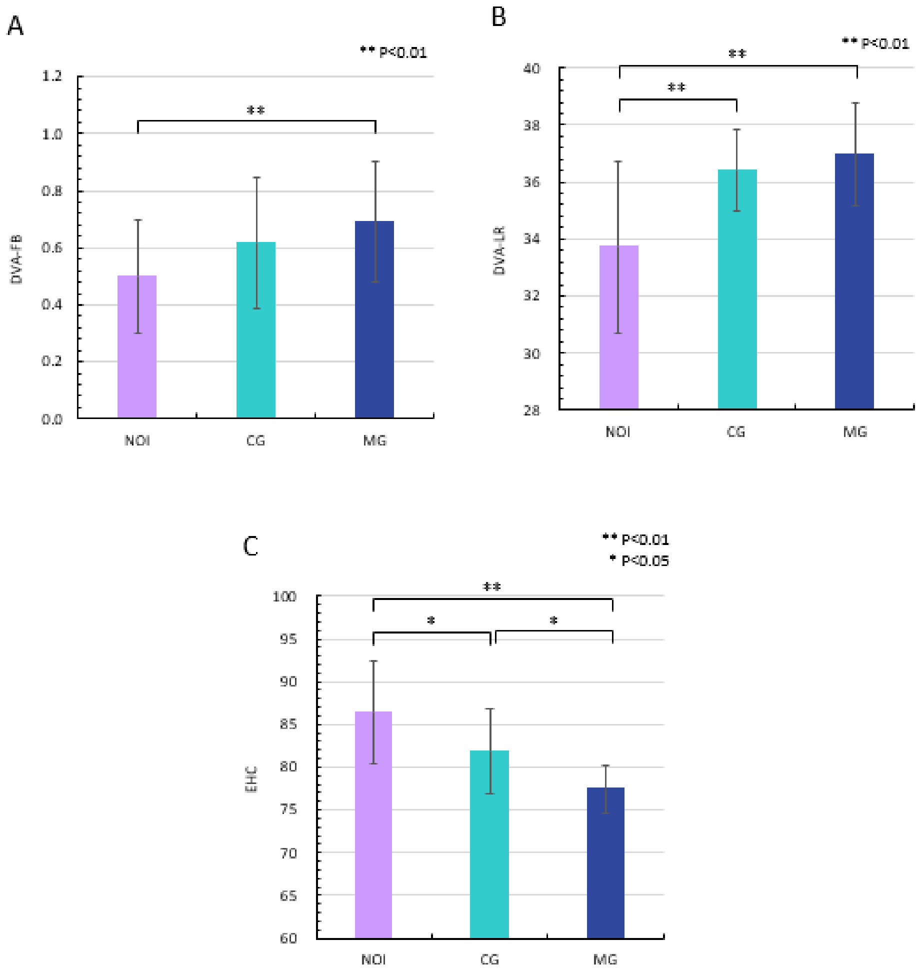

Figure 1: Effect of occlusal intervention on sports vision. A; DVA-FB, B; DVA-LR, C; EHC.

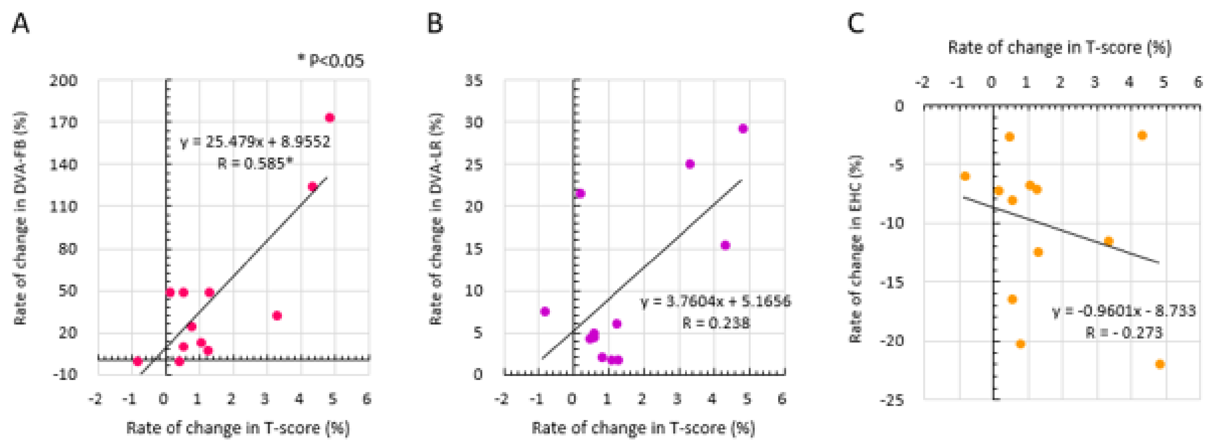

Figure 2: Correlation between the rate of change in T-score in straight jumps and the rate of change in sports vision due to wearing a mouthguard. A; DVA-FB, B; DVA-LR, C; EHC.

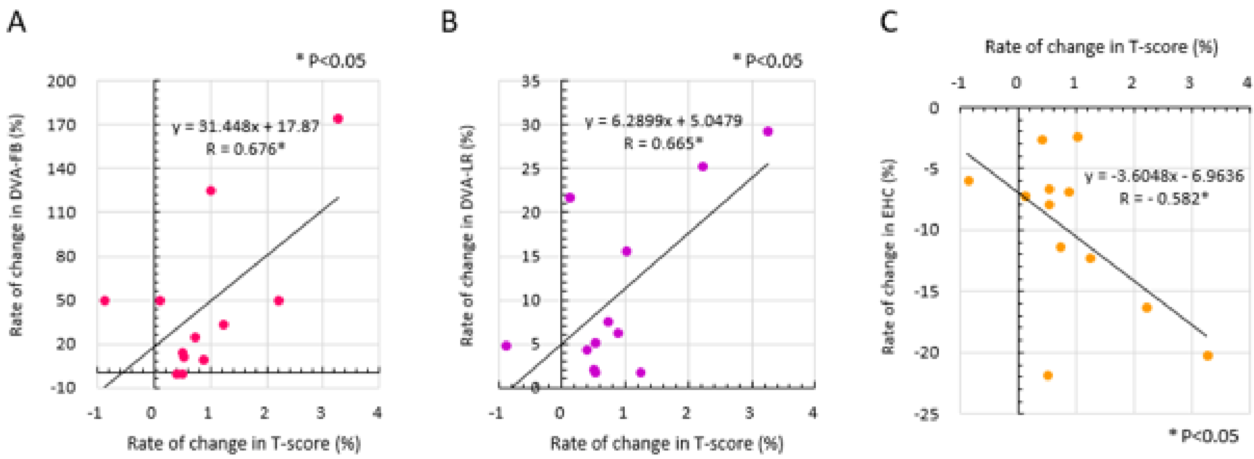

Figure 3: Correlation between the rate of change in T-score in barani jumps and the rate of change in sports vision due to wearing a mouthguard. A; DVA-FB, B; DVA-LR, C; EHC.

Discussion

The results of this study suggest that trampoline gymnasts' sports vision is affected by occlusal intervention. In addition, correlations were confirmed between the rate of change in sports vision and the rate of change in jump scores due to wearing a mouthguard, demonstrating that both are affected by occlusal intervention. Therefore, the null hypothesis was rejected.

Sports vision is assessed using multiple visual functions [1,16,17,22,23], and it has been reported that elite athletes tend to have better sports vision abilities [1]. Sports vision can be broadly grouped into the ability to quickly and accurately direct one's gaze toward a target, the ability to quickly and accurately recognize a captured target, and the ability to immediately react to a captured target and move accordingly [1], and the factors that are emphasized in sports vision may vary depending on the sport or event. In trampoline gymnastics, instantly recognizing the cross in the center of the bed while in the air corresponds to the ability to quickly and accurately direct one's gaze toward the target and quickly and accurately recognize the target, while adjusting one's posture to land on this cross corresponds to the ability to immediately react and move toward the target. The former can be assessed by depth perception and dynamic visual acuity, while the latter can be assessed by eye–hand coordination. In this study, we selected as participants trampoline gymnasts having long competitive careers; measured DVA-FB and DVA-LR as visual function-based landing position recognition abilities and EHC as a function of visual function to motor output; and examined the relationship with jumping skills.

The sensory inputs for postural control are primarily visual, somatosensory, and vestibular [7-9]. Sensory receptors related to occlusion are located in the periodontal ligament, temporomandibular joint, as well as jaw and neck muscles and are classified as somatosensory [24]. In the sensory integration of postural control, signals from somatosensory receptors are projected to the vestibular nuclei, which are involved in reflexes that regulate vision and neck movement. From this, it can be inferred that intervention in somatosensory input related to occlusion affects vision, vestibular sensation, and the postural control system that integrates them. For this reason, in this study, the CG and MG conditions were selected as a reversible, non-invasive method of occlusal intervention, and their effects on sports vision were confirmed. Furthermore, jumping skills during trampoline exercise were evaluated to investigate the effect of changes in sports vision due to the occlusal intervention on physical movement reflecting postural control. The occlusal intervention during trampoline jumping was limited to the MG condition due to safety considerations.

As shown in Figure 1, the impact of occlusal intervention on sports vision tended to be higher in the CG and MG conditions compared with NOI. In the CG and MG conditions, no instructions were given regarding chewing or clenching during the measurements, but muscle activity during the measurements was confirmed using an electromyograph attached to the masseter muscle. Although muscle activity was confirmed under all measurement conditions, the frequency tended to be higher under the CG and MG conditions compared with NOI. In both DVA-FB and DVA-LR, participants responded by pressing a switch once they identified the orientation of the Landolt ring. Because the movement speed of the Landolt ring is slow in the DVA-FB, it is considered that the influence of occlusal intervention on visual input was reflected in the measurements. However, because the Landolt ring moves at a fast speed in the DVA-LR, it is highly likely that the effects on visual input and motor output are mixed in the measurements. Regarding the measurements conducted in this study, it is difficult to ascertain whether the improvement in sports vision measurements resulting from occlusal intervention was due to the effect of projections from visual input to the vestibular nuclei or to the effect of the process from sensory integration to motor output. Furthermore, significant differences were observed among all measurement conditions in EHC, which directly reflects the impact on motor output, and the impact of occlusal intervention was more pronounced compared with the measurement results for dynamic visual acuity. These results suggest that sports vision improved as a result of occlusal intervention. The difference between CG and MG was observed only in EHC, with MG having the highest score. During the measurement of EHC, the reach distance of the upper arm is relatively long, which causes a shift in the center of gravity. Our previous research has shown that wearing a mouthguard with a good occlusal contact balance stabilizes both the static and dynamic center of gravity sway [10,11,25]. From this, it can be inferred that wearing a mouthguard facilitated smooth and stable movement of the center of gravity, which had an effect on EHC.

Next, we examined the relationship between trampoline jump scores and sports vision associated with occlusal intervention. We have previously confirmed that wearing a mouthguard affects the T-score and H-score of the straight jump as well as the T-score of the barani jump [19,26,27]. Therefore, in the present study, we calculated the rate of change associated with the mouthguard intervention and examined its relationship with the rate of change in sports vision. A significant positive correlation was found between the rate of change in DVA-FB and the rate of change in T-score for both straight jumps and barani jumps. DVA-FB evaluates the visual function of detecting the forward and backward movement of objects. During trampoline jumping, the cross in the center of the bed is instantly recognized during the later stage of the flight (i.e., while the body is descending) and then posture control is performed, so it can be assumed that forward and backward dynamic visual acuity is related to this. DVA-LR evaluates the visual function of detecting the movement of objects from side to side. Therefore, in vertical movements such as straight jumps, the side-to-side shift in the center of gravity is small, so a significant correlation may not have been observed. In contrast, barani jumps involve rotation and twisting, which causes a large shift in the center of gravity, and requires postural control during the rotation. This is probably why a correlation was also observed with DVA-LR. Because the EHC is an index that evaluates the ability to move the body in accordance with information perceived by the eyes, it can be inferred that this measurement item is the most relevant to jumping skills. In addition, because trampoline exercises require accurately capturing a target in a dynamic environment and initiating movement, we hypothesized that a stronger correlation would be observed in trials where vision was blocked from the cross on the bed (i.e., barani jump). From the analysis, there was no significant correlation for straight jumps, but a significant negative correlation was found for barani jumps. This suggests that occlusal intervention may be useful in environments where the distance between one's body and a target, such as an opposing player or a ball, changes. Sports vision is merely the ability to see, and improving it does not directly improve physical function. However, in terms of the judgment and postural adjustment required to control physical movement, these abilities are required in many sports and other competitive events, and can also have an impact on the prevention and reduction of sports injuries. Therefore, improving sports vision is necessary for athletes to maximize their physical abilities and play sports safely. The results of this study demonstrate that occlusal intervention has a positive effect on sports vision, suggesting the usefulness of chewing gum and wearing a mouthguard during sports.

The limitations of this study are that the target sport was limited to trampoline competition and that only male gymnasts were included. Because the sports vision required for various sports and disciplines differs, it is difficult to conclude from the results of this study whether the effects of occlusal intervention will be applicable to athletes in other sports. In the future, it will be necessary to expand the scope of the sports involved and conduct additional studies.

Conclusion

The results of this study revealed that sports vision in trampoline gymnasts is affected by occlusal intervention, with chewing gum improving dynamic visual acuity in the left/right direction and eye-hand coordination, and wearing a mouthguard improving dynamic visual acuity in the forward/backward and left/right directions as well as eye–hand coordination. Furthermore, the correlation between sports vision and the improvement rate of trampoline flight time due to wearing a mouthguard differed depending on the type of jump, with a correlation found between the dynamic visual acuity in the forward/backward direction in straight jumps, and between the dynamic visual acuity in the forward/backward and left/right directions as well as eye-hand coordination in barani jumps. In other words, it was suggested that performances involving rotations and twists were more closely related to sports vision.

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Conflicts of Interest statement

No conflicts of interest.

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