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RESEARCH ARTICLE

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Influence of Occlusion on Flight Time in Trampoline Competition

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Abstract

Purpose: The aim of this study was to clarify the effect of occlusion on flight time in trampoline competition.

Materials and methods: Participants were 10 male trampoline gymnasts (18.9 ± 0.8 years). Dental Prescale was used to measure the occlusal contact state, and the lateral difference in the occlusal contact area was calculated. An all-in-one measurement system (HDTS EU-7100) was used to measure the flight time during consisted of 10 consecutive straight jumps. The correlation between the lateral difference in occlusal contact area and flight time was analyzed using Pearson's product-moment correlation coefficient. A custom mouthguard was fabricated using a 2.0-mm-thick thermoplastic sheet and was adjusted so that all teeth were in even contact with light clenching. Differences in flight times with and without a mouthguard were compared using a paired t-test. Spearman's rank correlation coefficient was used to analyze the relationship between the lateral difference in occlusal contact area and the rate of flight-time prolongation due to wearing a mouthguard.

Results: A negative correlation was observed between the lateral difference in occlusal contact area and flight time ($P<0.05$, $R=-0.697$). As a result of comparing the flight time with and without a mouthguard, flight time was significantly longer with a mouthguard ($P<0.05$). A significant positive correlation was observed between the lateral difference in occlusal contact area and the extension rate of flight time due to wearing a mouthguard ($P<0.05$, $R=0.657$).

Conclusion: This study revealed a relationship between occlusion and flight time during straight jumps in the trampoline competition and found that the smaller the left-right difference in the occlusal contact area, the longer the flight time. In addition, it was clarified that achieving uniform occlusal contact by wearing a mouthguard contributed to the extension of flight time, and this effect was more pronounced in athletes with uneven occlusal contact.

Keywords: Occlusion; Occlusal contact state; Flight time; Trampoline competition; Oral appliance; Mouthguard

Introduction

The trampoline competition is an event consisting of 10 jumps in which different techniques are performed consecutively during a total flight time of about 20 s [1-4]. There are four scoring items: the performance score for evaluating the performance of the technique (E-score), the difficulty score for evaluating the number of rotations and twists (D-score), the flight-time score (T-score), and the score for evaluating the horizontal landing position from the center of the bed (H-score). Balance stability during jumping, including air posture and landing posture, influences performance. The T- and H-scores reflect postural control, while a low jumping height reduces the number of rotations in somersaults and twists, resulting in a low D-score. For this reason, elite-level athletes tend to have higher T- and D-scores [1]. The straight jump, which is the most basic exercise in trampoline competitions, uses the strong repulsive force of the bed transmitted from the soles of the feet to maintain a standing posture in mid-air [4]. While in the air, it is necessary to recognize the position of the center of the bed, assume an aerial posture, and control the movement of one's body. Therefore, in the trampoline competition, it is important to have fine postural control, spatial cognition, and sports vision [2].

Our previous study on occlusion, which is one of the main factors in postural control function, focused on trampoline gymnasts [3]. A clear relationship was found between the occlusal contact state and the displacement of the center of foot pressure. It was revealed that trampoline gymnasts with good occlusal contact state tended to have a small outer peripheral area and a large unit area trajectory length.

The outer peripheral area indicates the amount of movement from the origin of the center of gravity, and the unit area trajectory length is used as a parameter indicating the fineness of postural control [3,5-10]. From this, it was clarified that the occlusal contact state is involved in fine postural control.

The aim of this study was to clarify the effect of occlusion on flight time in trampoline competition. To this end, the relationship between the occlusal contact state and the flight time of trampoline gymnasts was investigated, and the effect on the flight time of wearing an oral appliance that corrects the occlusal contact state was examined. The null hypothesis was that the flight time in trampoline competitions is not affected by occlusal contact state.

Materials and Methods

Ethical approval of studies and informed consent

This study was approved by the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (ECNG-R-375). The details of the study were described in full to all participants, and written informed consent was obtained from all participants prior to their participation.

Participants

Participants were 10 male trampoline gymnasts (age, 18.9 ± 0.8 years). All athletes were elite level with at least 12 years of competitive experience. All participants had no tooth loss except for the third molar and no subjective or objective abnormalities in the stomatognathic system were observed.

Measurement of the occlusal state

The occlusal contact state was measured using a pressure-sensitive film (Dental Prescale, 50H-R type; Fujifilm Co., Ltd., Tokyo, Japan), and evaluation was performed using the manufacturer's dedicated analysis device (Occluzer FPD-709; Fujifilm Co., Ltd.) [3,7,11,12].

The pressure-sensitive film was inserted into the mouth of each participant, and they were instructed to clench their teeth at maximum force for 3 s in the intercuspal position. The pressure-sensitive film was then removed and the left–right difference (%) in occlusal contact state was calculated by the analysis device (Figure 1). One measurement was performed for each participant.

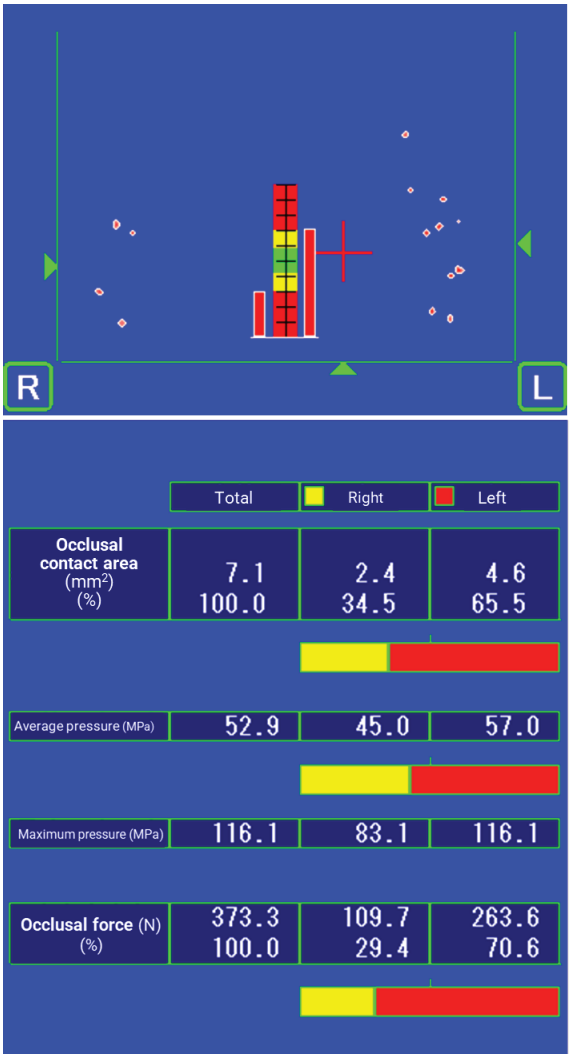


Figure 1: Analysis results of occlusal contact state using Occluzer (FPD-709).

Mouthguard fabrication

A custom mouthguard was fabricated for each participant, using a 2.0-mm-thick thermoplastic sheet (Sports Mouthguard; Keystone Industries, Cherry Hill, NJ) and a pressure molding machine (Model Capture; Shofu Inc., Kyoto, Japan). The amount of occlusal elevation was within the freeway space and was adjusted so that all teeth were in even contact with light clenching (Figure 2) [3].

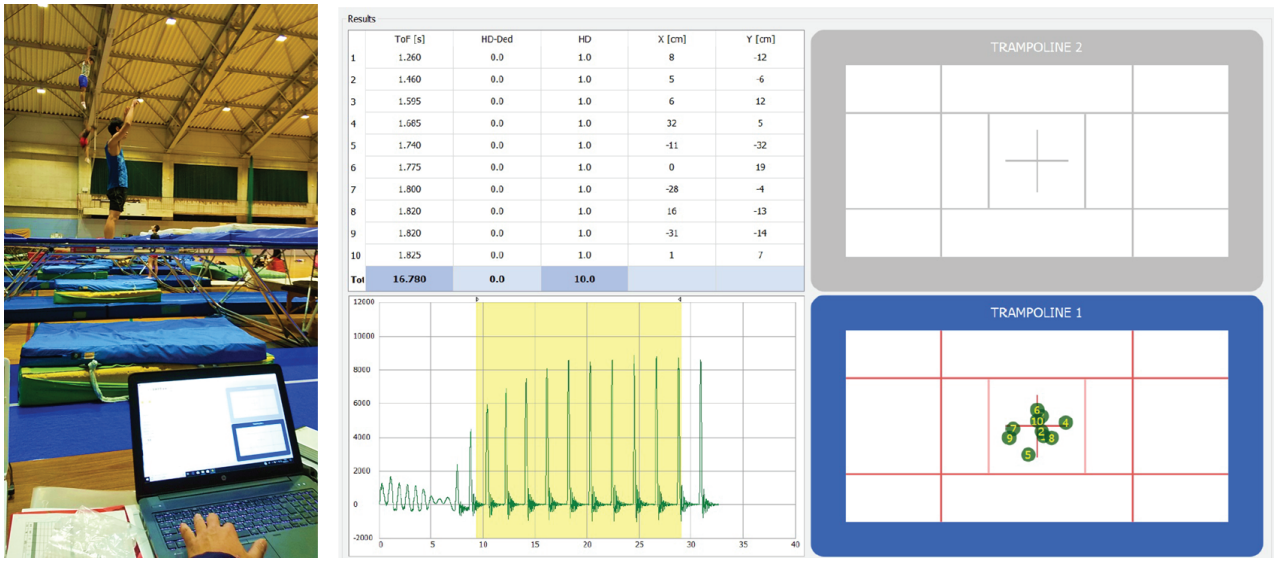
Figure 2: Fabrication and adjustment of custom mouthguards.

Measurement of flight time in straight jump

An all-in-one measurement system (HDTS EU-7100; Eurotramp, Weilheim an der Teck, Germany) was used to measure the time of flight. After performing calibration, recording was started (Figure 3). The time away from the bed was recorded as the flight time for each jump, and the flight time of 10 consecutive straight jumps was recorded. Recordings were made three times when the participant was not wearing a mouthguard and three times when they were.

Statistical analysis

Statistical analysis was performed using IBM SPSS 24.0 (SPSS Japan Inc., Tokyo, Japan). For all measured values, the Shapiro-Wilk test was



	ToF [s]	HD-Ded	HD	X [cm]	Y [cm]
1	1.260	0.0	1.0	8	-12
2	1.460	0.0	1.0	5	-6
3	1.595	0.0	1.0	6	12
4	1.685	0.0	1.0	32	5
5	1.740	0.0	1.0	-11	-32
6	1.775	0.0	1.0	0	19
7	1.800	0.0	1.0	-28	-4
8	1.820	0.0	1.0	16	-13
9	1.820	0.0	1.0	-31	-14
10	1.825	0.0	1.0	1	7
Tot	16.780	0.0	10.0		

Figure 3: Flight time measurement using an all-in-one measurement system (HDTS EU-7100).

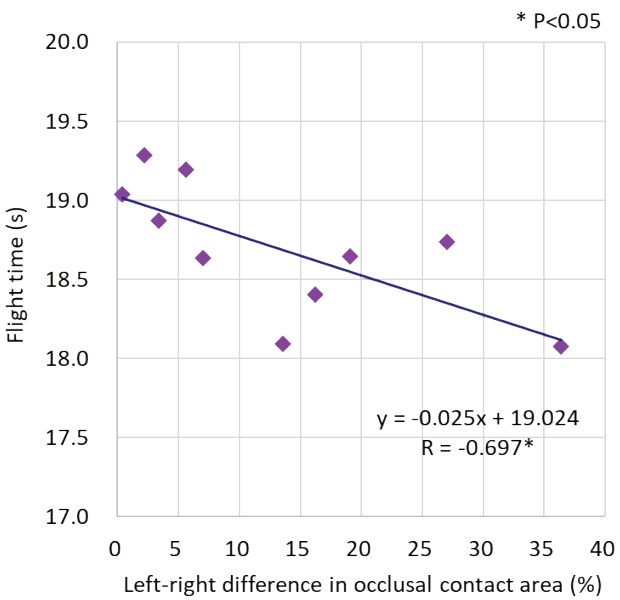


Figure 4: Correlation between left-right difference in occlusal contact area and flight time without mouthguard. A strong negative correlation was observed (P<0.05, R=−0.697), and participants with small left–right differences in occlusal contact area tended to have longer flight times.

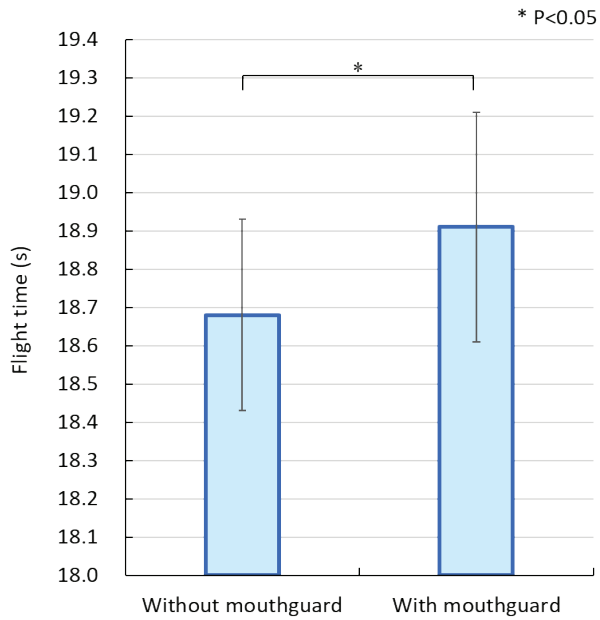


Figure 5: Comparison of flight time with and without a mouthguard. Measurements are expressed as means ± SD. Error bar indicates standard error of the mean. *: statistical significance (critical region; *P<0.05). The flight time was significantly longer with a mouthguard (P<0.05).

used for the normality test. Normality was observed in the variables for left–right difference in the occlusal contact area, flight time without a mouthguard, and flight time with a mouthguard. Normality was not observed in the variable for the rate of flight time extension due to wearing a mouthguard. Therefore, Pearson's product-moment correlation coefficient was used to analyze the correlation between the left-right difference in occlusal contact area and the flight time without a mouthguard. Next, the differences in flight time with and without a mouthguard were analyzed using the paired t-test. Subsequently, a correlation analysis was performed between the left-right difference in occlusal contact area and the rate of flight-time prolongation due to wearing a mouthguard, using Spearman's rank correlation coefficient. Significance was set at P<0.05.

Results

A strong negative correlation was observed between the left–right difference in the occlusal contact area and flight time without a mouthguard (P<0.05, R=-0.697). Participants with small left-right

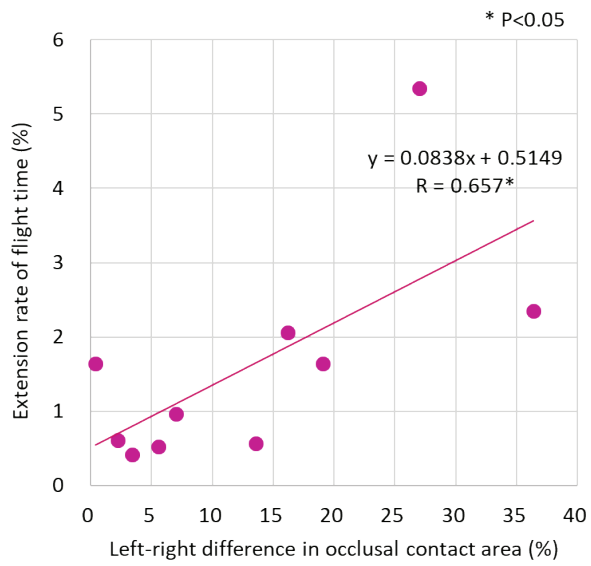


Figure 6: Correlation between left-right difference in occlusal contact area and extension rate of flight time due to wearing a mouthguard. A significant positive correlation was observed (P<0.05, R=0.657), and participants with larger left-right differences in occlusal contact area had a greater increase in the extension rate of flight time.

differences in occlusal contact area tended to have longer flight times (Figure 4).

Comparison of flight times with and without a mouthguard showed that flight time was significantly longer with a mouthguard (P<0.05) (Figure 5).

A significant positive correlation was observed between the left–right difference in the occlusal contact area and the extension rate of flight time due to wearing a mouthguard (P<0.05, R=0.657). Participants with larger left-right differences in occlusal contact area had a greater increase in the extension rate of flight time (Figure 6).

Discussion

The results of this study revealed that flight time in the trampoline competition was affected by the occlusal contact state and was significantly prolonged by wearing a mouthguard that provided even occlusal contact; therefore, the null hypothesis was rejected.

There are several reports on the relationship between occlusion and physical function, the findings of which can be summarized as follows: equalization of occlusal contact by wearing a mouthguard reduces static center-of-gravity sway; strong occlusal force is an important factor in muscle strengthening; and occlusal force and the stability of occlusal contact are related to agility during competition [3,11-13]. These findings suggest that occlusion affects body balance, muscle strength, and agility, and may also affect athletic performance.

The trampoline competition was added as a new gymnastics' competition at the Sydney Olympics in 2000. This competition grew out of an exercise designed to cultivate the sense of balance and coordination required in military pilots during flight [1,14]. Accordingly, it was predicted that postural control function in the trampoline competition would directly affect performance. Based on these findings, it was inferred that the state of occlusal contact, which has been shown to be related to postural control in a previous study [3], would affect performance in the trampoline competition. Therefore, this study investigated the effect of occlusal contact state on flight time in the trampoline competition.

In this study, a significant and strong negative correlation was observed between the left-right difference in the occlusal contact area and the flight time when the mouthguard was not worn. It became clear that trampoline gymnasts with even occlusal contact tended to have longer flight times. The straight jump is a basic jump in the trampoline competition, during which the repulsive force of the bed is used to maintain a standing posture in the air [4]. If the landing position is in the center of the bed, the flight time will be longer because the bed will bounce the body vertically. However, if the landing position deviates from the center position, the repulsive force of the bed that bounces off both feet will differ, and the flight time will be shortened because the long axis of the body will be tilted. Therefore, to minimize the influence of factors other than body structure on the measured values, straight jumps were selected for the trials in this study because they do not involve rotation or twisting. Flight-time evaluation was performed using the HDTS all-in-one measurement system, which can accurately evaluate the time the body is away from the bed by using external pressure sensors installed on the four legs of the trampoline device. A precision instrument used for scoring H-scores and T-scores in international competitions was selected. The results clarified that the left–right difference in the occlusal contact area is affected by the flight time, suggesting the possibility that flight time might be extended by improving or correcting the occlusal contact state.

This study investigated the effect on flight time of wearing a mouthguard, an intraoral device that corrects the occlusal contact state. The sensation of wearing a mouthguard, including the thickness, fit, and occlusal stability, can have a large impact on the measured values. All 10 participants had experience wearing a mouthguard, but not during trampoline competitions. The amount of occlusal elevation of the mouthguard was adjusted to a mandibular position without deviation, with the amount of occlusal elevation remaining within the freeway space and a slight rotation of the mandibular condyle [3]. Additionally, athletes who felt discomfort or could not concentrate during the trial because of the mouthguard were excluded from participation. The results of this study indicate that wearing a mouthguard with uniform occlusal contact significantly increases flight time. All participants were conscious of clenching their teeth as they prepared to land on the bed. It was considered that the occlusal contact state might have affected postural control function at this time.

In addition, a positive correlation was observed between the left-right difference in the occlusal contact area and the rate of flight time extension, indicating that wearing an oral appliance had a positive effect on flight time in participants with poor occlusal contact. In other words, wearing a mouthguard did not great affect flight time in participants who had good occlusal contact. In this study, 3 of the 10 participants had uniform occlusal contact with a left-right difference in the occlusal contact area of less than 5%, while 5 had uneven occlusal contact with a left-right difference in the occlusal contact area of 10% or more. Participants in this study had a large proportion of those with poor occlusal contact. Therefore, it is possible that wearing an oral appliance resulted in a significant effect on flight time. The main finding of this study is that although wearing an oral appliance may not be useful for all athletes in terms of improving their athletic performance, it is useful for athletes with uneven occlusal contact. It was thus inferred that occlusion may have a great impact on the take-off motion in the trampoline competition. Efficient take-off motion is essential for the subsequent flight, which makes the most

of the repulsive force of the bed. When an efficient take-off motion is executed, a good jump height and flight time (T-score) can be achieved. Furthermore, extending the flight time can also affect the difficulty of the jump (D-score) by increasing the number of rotations and twists. Therefore, the findings of this study suggest the potential impact of occlusion on overall performance in the trampoline competition.

There are two main limitations of this research. The first is the small number of participants. This was the result of targeting elite-level athletes with more than 12 years of athletic experience. In the future, it will be necessary to increase the number of participants and compare the results. The second limitation is that the amount of muscle activity and the movement of the posture-maintaining muscles during the trial were not analyzed. In the future, it will be necessary to verify the occurrence and degree of clenching during the take-off motion as well as the timing and duration of contraction in posture-maintaining muscles. Through these verifications, it should be possible to clarify which timing of the performance is greatly affected by occlusion.

Conclusion

This study investigated the relationship between occlusal contact area and flight time during straight jumps in order to clarify the effect of occlusion on flight time in trampoline competitions. According to this study, it was suggested that the smaller the left–right difference in the occlusal contact area, the longer the flight time. Additionally, it was clarified that achieving uniform occlusal contact by wearing a mouthguard contributed to the extension of flight time, and this effect was suggested to be more pronounced in athletes with uneven occlusal contact.

Data Availability

The datasets collected and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments

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Conflicts of Interest Statement

The authors have no conflicts of interest relevant to this article

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