

# Correction of Occlusal Contact Condition Affects Flight Time of Barani Jumps on Competitive Trampoline

Mutsumi Takahashi<sup>1\*</sup>, Yogetsu Bando<sup>2</sup>, Takuya Fukui<sup>3,4</sup>

<sup>1</sup>Department of Physiology, The Nippon Dental University School of Life Dentistry at Niigata, Niigata, Japan

<sup>2</sup>Bando Dental Clinic, Ishikawa, Japan

<sup>3</sup>Department of Sport Science, Kanazawa Gakuin University of Sport Science, Ishikawa, Japan

<sup>4</sup>Japan Gymnastics Association Trampoline Committee, Tokyo, Japan

Email: \*mutsumit@ngt.ndu.ac.jp

**How to cite this paper:** Takahashi, M., Bando, Y., & Fukui, T. (2025). Correction of Occlusal Contact Condition Affects Flight Time of Barani Jumps in Competitive Trampoline. *Advances in Physical Education*, 15, 197-207.

<https://doi.org/10.4236/ape.2025.152015>

**Received:** February 27, 2025

**Accepted:** May 10, 2025

**Published:** May 13, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

## Abstract

**Purpose:** The aim of this study was to clarify the effect of occlusal correction using an intraoral appliance on flight time during barani jumps in trampoline competitions. **Method:** Thirteen male trampoline gymnasts ( $17.5 \pm 2.4$  years) were selected as participants. Custom mouthguards were fabricated for each gymnast and were adjusted so that all teeth were in even contact with light clenching. The trial consisted of 10 consecutive barani jumps. Flight time was measured using an HDTS all-in-one measurement system. Measurements were performed at three time points: before the participant wore the mouthguard, immediately after wearing, and 2 months after wearing. Differences among measurement time points in the maximum flight time for one jump and the total flight time for 10 consecutive jumps were compared using one-way analysis of variance using repeated measurements. **Results:** Two months after participants started wearing the mouthguard, the maximum flight time for one jump was significantly longer than the before time point ( $P < 0.05$ ). There were significant differences between immediate and 2 months after participants started wearing the mouthguard ( $P < 0.05$ ) and between before and 2 months after participants started wearing the mouthguard ( $P < 0.01$ ), with the total flight time of 10 consecutive jumps being the highest at the 2-month time point. **Conclusion:** The results of this study suggest that the flight time of continuous barani jumps in competitive trampoline is affected by wearing an oral appliance and that occlusal correction contributes to an extended flight time. The findings also suggest that a certain period of training is required to achieve this effect.

---

## Keywords

Trampoline Competition, Flight Time, Barani Jump, Occlusion, Oral Appliance, Mouthguard

---

## 1. Introduction

Competitive trampoline is an international gymnastics competition in which 10 consecutive trampoline performances are scored on four criteria. Scoring comprises a performance difficulty score (D-score), performance score (E-score), jump time score (T-score), and movement deduction score (H-score). The D-score is evaluated by judges using the number of somersaults and twists and the posture of each performance, whereas the E-score is evaluated using posture maintenance and stability, including landing (Izumi, 2018; Federation Internationale de Gymnastique, 2025). The T-score and H-score are electronically scored by an HDTs system installed on the legs supporting the trampoline bed (Ferber et al., 2019; Federation Internationale de Gymnastique, 2025). The first performance begins at the gymnast's own timing, after the gymnast has secured sufficient height through repeated straight jumps.

The straight jump is an action that uses the strong reaction force of the bed transmitted from the soles of the gymnast's feet to maintain an upright posture while the gymnast is in the air (Ito et al., 2000). Postural stability is an important bodily function for maintaining an upright posture. In addition to the fixation of the musculoskeletal system, trunk stability can be influenced by the effect of sensory input on posture control (Uchiyama, 1995; Takei, 2013; Itaya, 2015; Robert & Amanda, 2019). To prove the influence of this mechanism on athletes, our research has focused on occlusion, which has the potential to influence somatosensory input and vestibular sensory input (Bando et al., 2019; Takahashi et al., 2023c, 2023d, 2023e). Our results showed that occlusal correction using a mouthguard improved static balance (Bando et al., 2019; Takahashi et al., 2023c), that the landing position of straight jumps was correlated with the direction of the displacement of the center of gravity in trampoline gymnasts with good left-right balance of occlusal contact (Takahashi et al., 2023e), and that occlusal correction for trampoline gymnasts with poor left-right balance of occlusal contacts increased the flight time of a straight jump (Takahashi et al., 2023d). These findings revealed that occlusal correction affects postural stability and motor function, which involves postural adjustment.

In competitive trampoline, the flight time for each performance not only directly affects the T-score, but also the performance and appearance of highly difficult techniques (Heinen & Krepela, 2016; Shintani et al., 2022). Therefore, any extension of the flight time may also affect the D-score and E-score and may influence the scoring (Heinen & Krepela, 2016; Shintani et al., 2022). Because the take-off motion has a large effect on increasing the flight time, our research team

has previously investigated the relationship between the sensory input related to occlusion by selecting straight jumps as a trial movement (Takahashi et al., 2023d, 2023e; Bando et al., 2023). However, given that actual competitions involve mainly rotations and twists, it is necessary to investigate the effects of occlusion in performances that include these movements.

The purpose of this study was to clarify the effect of occlusal correction using an intraoral appliance on flight time during barani jumps in trampoline competitions. The null hypothesis was that flight time during the barani jump is not affected by occlusal correction.

## 2. Materials and Methods

### 2.1. Ethical Approval of Studies 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 before their participation.

### 2.2. Participants

Thirteen male trampoline gymnasts (mean age,  $17.5 \pm 2.4$  years) were selected as participants. They had no subjective or objective morphological or functional abnormality in the stomatognathic system. The average length of competitive experience was  $11.8 \pm 2.6$  years and the participants were currently training 6 times a week for 3 h each session.

### 2.3. Fabrication of Custom Mouthguard

Custom 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 correction of the shape and polishing, the mouthguard was fitted into each gymnast's mouth and adjusted so that all teeth were in even contact with light clenching (Bando et al., 2019; Takahashi et al., 2023b, 2023c). The state of the occlusal contact of the mouthguard was confirmed by occlusal examination using blue silicone (Bite Eye; GC Co., Tokyo, Japan), and the difference in occlusal contact area between the left and right sides was adjusted to be less than 10% (Takahashi et al., 2023b). Gymnasts who felt a foreign body sensation or discomfort while wearing a mouthguard were excluded from the participants.

### 2.4. Recording of Barani Jump Flight Time

The barani jump is a trampoline technique in which the individual performs a 1/2 turn to the side while performing a 1-turn forward somersault. In this study, 10

consecutive barani jumps performed after one backward somersault were considered one trial. The time of flight was measured using an HDTS all-in-one measurement system (EU-7100; Eurotramp Trampoline Kurt Hack GmbH, Weilheim, Germany). Measurements were started after calibration of the system, which then recorded the flight time for each jump and the total time for the 10 jumps (T-score) (Figure 1) (Takahashi et al., 2023a, 2023d). Measurements were performed three times at each of the three time points: before the participant wore the mouthguard, immediately after the participant started wearing the mouthguard, and 2 months after the participant started wearing the mouthguard. Gymnasts were instructed in advance to wear the mouthguard for just under half of their practice days.

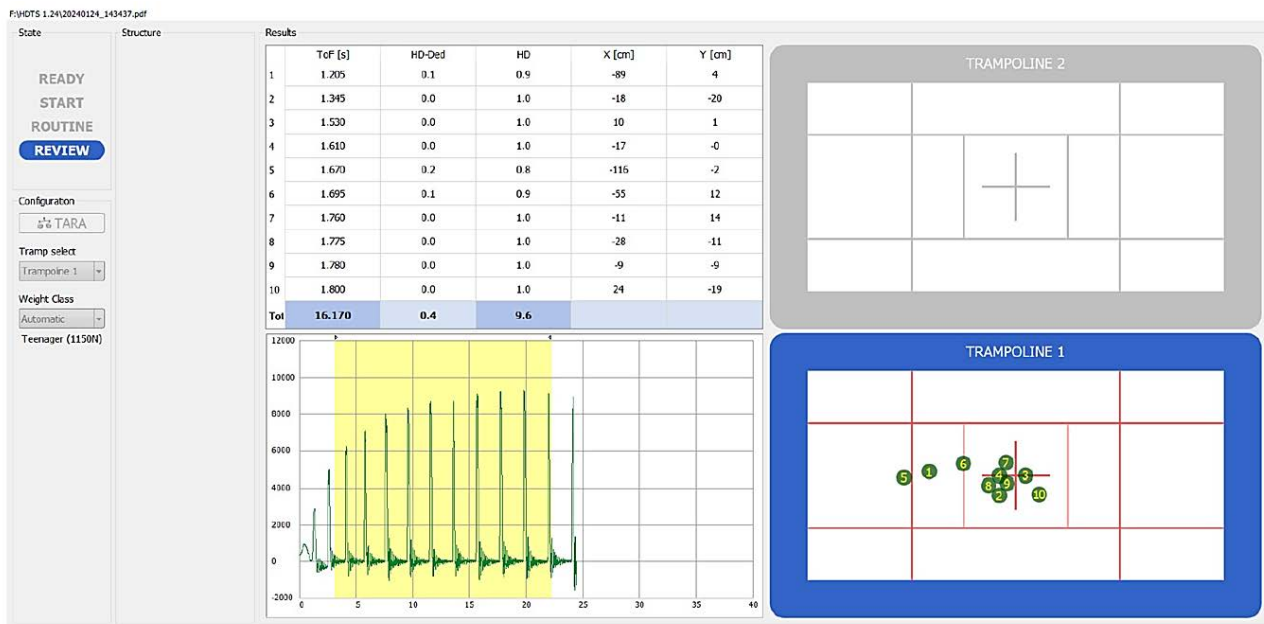


Figure 1. Example of the flight time measurement results obtained using HDTS.

## 2.5. Statistical Analysis

Statistical analyses were conducted 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, and normality was observed for each level of flight time.

A statistical analysis was conducted to examine the effect of wearing a mouthguard and the duration of wearing it on flight time. Differences among measurement time points in the maximum flight time for one jump and the total flight time for 10 consecutive jumps (T-score) were compared using one-way analysis of variance using repeated measurements. Subsequently, multiple comparison tests between levels were performed using the Bonferroni method.

## 3. Results

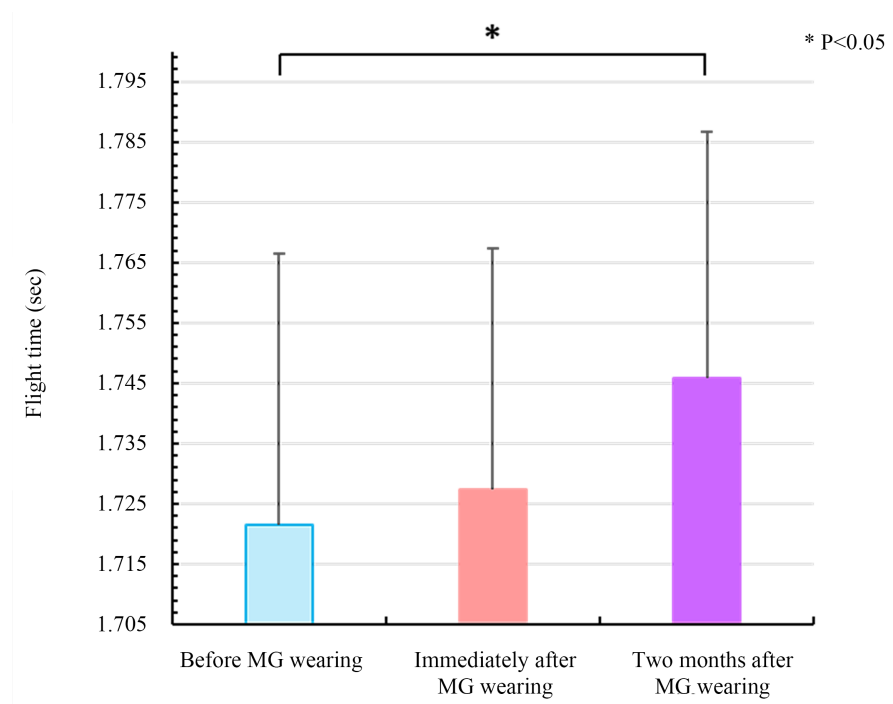
Regarding the differences in the maximum flight time for one jump, the results of

one-way analysis of variance with repeated measures are shown in **Table 1** while the results of multiple comparison tests using the Bonferroni method are shown in **Figure 2**. No significant differences were observed between before and immediately after participants started wearing the mouthguard. Two months after participants started wearing the mouthguard, flight time was significantly longer than the before time point ( $P < 0.05$ ).

**Table 1.** Results of one-way repeated measures analysis of variance of the difference in the maximum flight time for one jump by measurement time point.

Source	<i>df</i>	MS	F value	<i>P</i> value
Measurement time point	2	0.002	5.452	0.011*
Error	24	0.000		
Total	26	0.002		

*df*, degree of freedom; MS, mean square. \* $P < 0.05$ , denotes statistically significant difference.



**Figure 2.** Difference in the maximum flight time for one jump at different measurement time points. Error bar indicates the standard error of the mean. \* $P < 0.05$ : denotes statistically significant difference. MG, mouthguard.

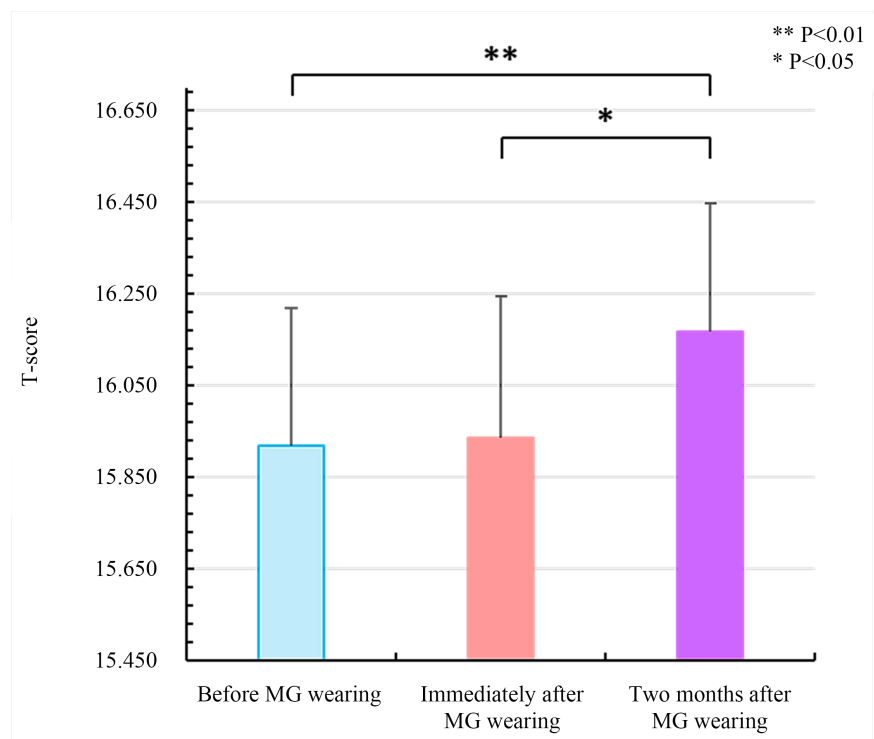
**Table 2** shows the results of one-way analysis of variance with repeated measures for the difference in the total flight time of 10 consecutive jumps (T-score) at different measurement time points. **Figure 3** shows the results of multiple comparison tests using the Bonferroni method. No significant difference was observed between before and immediately after participants started wearing the mouthguard. However, there were significant differences between immediately

and 2 months after participants started wearing the mouthguard ( $P < 0.05$ ) and between before and 2 months after participants started wearing the mouthguard ( $P < 0.01$ ), with the score being highest at the 2-month time point.

**Table 2.** Results of one-way repeated measures analysis of variance of the difference in the total flight time of 10 consecutive jumps (T-score) by measurement time point.

Source	<i>df</i>	MS	F value	<i>P</i> value
Measurement time point	2	0.255	6.573	0.005**
Error	24	0.039		
Total	26	0.294		

*df*, degree of freedom; MS, mean square. \*\* $P < 0.01$ , denotes statistically significant difference.



**Figure 3.** Difference in the total flight time of 10 consecutive jumps (T-score) at different measurement time points. Error bar indicates the standard error of the mean. \*\* $P < 0.01$ , \* $P < 0.05$ : denotes statistically significant difference. MG, mouthguard.

#### 4. Discussion

The results of this study showed that occlusal correction using an intraoral appliance increased the flight time of barani jumps in competitive trampolines gymnasts. Therefore, the null hypothesis that occlusal correction did not affect flight time during the barani jump was rejected.

Flight time during a trampoline jump is an important factor in the evaluation of competitive ability. Generally, the longer the flight time, the higher the jump. Because trampoline routines are performed while the athlete is in the air and the

latter half of the air phase is spent preparing for landing, a higher jump enables the athlete to attempt more difficult movements and to perform a more visually impactful routine (Shintani et al., 2022). The T-score is determined by calculating the total flight time of the 10 performances in seconds. Therefore, a longer flight time is required to improve the D-score and E-score. The two main factors that greatly affect flight time are the landing position and the take-off motion. To efficiently utilize the spring elasticity of the trampoline bed to bounce the gymnast's body vertically, it is most effective to land in the center of the bed. Moreover, because this landing position is evaluated as the H-score, it can be inferred that the T-score is influenced by the H-score. Furthermore, regarding the take-off motion, the extensor muscles of the hip and knee joints have been reported to play a major role in maintaining the posture upon landing (Qian et al., 2020), and this makes it so that the trampoline bed can sink downward and produce a large reaction force (Matsushima & Yano, 2018). In this regard, our previous work has shown that the hip joint range of motion and dynamic balance are affected by occlusal contact state and clenching (Takahashi et al., 2024a). In addition, the masseter, temporalis, and sternocleidomastoid muscles, which are active during clenching, have a fascial linkage with the deep trunk muscles and contribute to posture maintenance (Thomas, 2016; Robert & Amanda, 2019). Because postural stability during clenching depends on the occlusal contact state (Takahashi et al., 2023c, 2024b), occlusal correction using an intraoral appliance should affect flight time and landing position in trampoline competitions.

To verify these points, prior work from our research group has investigated the effects of gymnasts' left-right balance of occlusal contact and the wearing of a mouthguard on their flight time and landing posture during straight jumps, which are the basic trials of trampoline competitions (Takahashi et al., 2023d; Bando et al., 2023). These studies confirmed that the state of occlusal contact influences the flight time and landing position. However, because actual competitions involve mainly movements that include rotations and twists, it was not clear whether the results of the study using straight jumps as trial techniques would also apply to actual competitions. There are multiple elements to the movement of trampoline performance, and each gymnast is good at different movements. In order to determine the effectiveness of occlusal intervention, we determined that a trial of basic trampoline skills would be an appropriate way to evaluate with less bias. The barani jump is one of the basic trampoline maneuvers that involves rotation and twisting, and can be used to evaluate the ability to gradually increase the jump height through continuous jumps. Therefore, the present study investigated the effect of occlusal correction using a mouthguard on flight time using barani jump as a test skill.

In this study, the maximum flight time for one jump was slightly improved immediately after the participants started wearing the mouthguard compared with before they started wearing the mouthguard, but no significant difference was observed until the 2-month time point. In addition, significant differences were ob-

served in the total flight time of 10 consecutive jumps (T-score) between before and after 2 months of mouthguard wearing and between immediately and after 2 months of mouthguard wearing. Our previous examination of straight jumps as a trial skill (Takahashi et al., 2023d; Bando et al., 2023) suggested that occlusal correction using a mouthguard made it easier to land in the center of the bed, but because this lengthened the flight time, several gymnasts found that the timing of entering the next landing position did not match the learned timing. These gymnasts adjusted their take-offs mid-trial to match the timing to which they were accustomed. This tended to shorten their flight times. In this study, many gymnasts recorded their maximum flight time during their 8th to 10th jumps, and this tendency was almost the same regardless of the measurement time point. This is likely due to the fact that the barani jump is a trial to gradually increase the jumping height during repeated jumps. Additionally, compared with straight jumps, barani jumps may be influenced by the fact that gymnasts are more aware of the jump height than the landing position.

Regarding the difference in flight time between immediately and 2 months after wearing the mouthguard, there was no significant difference in the maximum value for one jump between the two time points, but the total time for 10 jumps (T-score) was significantly improved 2 months after participants started wearing the mouthguard. These results indicate that the gymnasts were able to jump higher in each jump after wearing the oral appliance for a period of time. In other words, this supports the involvement of occlusion in a stable landing posture and take-off motion. Furthermore, considering that no significant differences were observed between before and immediately after wearing the mouthguard in any of the analyses, it may be that, for occlusal correction to positively influence jump performances that involve rotation and twisting in trampoline competitions, a certain period of training may be required for each gymnast to master the timing of the take-off movement and airborne posture. The effects of the intervention were measured after two months because their coach determined that most gymnasts had become accustomed to the mouthguards at that point. Since it is assumed that the getting used to wearing a mouthguard is vary among individuals, we plan to increase the number of measurement points in the future to observe changes over time, as well as to examine the effects on psychological factors.

From the above, it became clear that the flight time of consecutive barani jumps in competitive trampoline is affected by occlusal correction using an intraoral appliance and that a certain period of training is required to improve flight time. The gymnasts in this study had an average age of 17.5 years and an average competitive experience of 11.8 years, which meant that there was little variation in each trial, making it easier to discern the effects of the intervention. However, given that the take-off movements, landing posture, and timing that have been learned by each gymnast are well established, it may take time for them to adapt to the intervention. In particular, regarding interventions that affect landing pos-

ture and timing, as examples, research plans must take into account the possibility of serious accidents related to trampoline competition. For that reason, the jump attempted in this study was the relatively simple barani jump. However, in actual competitions, more acrobatic and diverse movements are performed in succession, so it is necessary to consider training methods based on the premise of utilizing the effects of occlusal intervention to improve competitive ability, as well as the age range for intervention.

The main limitations of this study are the small number of gymnasts included and the inclusion of male gymnasts only. The trial in this study involved jumps involving rotation and twisting, and because mouthguard intervention may affect postural stability (Bando et al., 2019; Takahashi et al., 2023b, 2023c, 2024a), we selected gymnasts with a certain level of competitive experience for safety reasons. In addition, because the menstrual cycle can have a significant effect on physical function in women (Emami et al., 2019; Lee et al., 2017), the timing of measurement should be carefully considered when selecting participants. For these reasons, only male gymnasts with 8 to 16 years of competitive experience were included as participants in this study. Another limitation is that the effects after discontinuing the intervention were not determined. In the future, it will be necessary to secure a sufficient number of participants over time in order to compare the effects of the mouthguard intervention with a control group and to verify the effects after the intervention has ended.

## 5. Conclusion

The results of this study suggest that the flight time of continuous barani jumps in competitive trampoline is affected by wearing an oral appliance and that occlusal correction contributes to an extended flight time. The findings also suggest that a certain period of training is required to achieve this effect.

## Funding

This work was supported by JSPS KAKENHI Grant Number JP23K10617.

## Conflicts of Interest

The authors have no conflicts of interest relevant to this article.

## References

- Bando, Y., Takahashi, M., & Fukui, T. (2023). Effect of Occlusal State of Elite Athletes on H-Score in Trampoline Competitions. *Journal of Sports Dentistry*, 26, 1-6.
- Bando, Y., Takahashi, M., Fukui, T., Maruyama, A., & Sugita, M. (2019). Relationship between Occlusal State and Posture Control Function of Trampoline Gymnasts. *Journal of Sports Dentistry*, 23, 14-20.
- Emami, F., Kordi Yoosefinejad, A., & Motealleh, A. (2019). Comparison of Static and Dynamic Balance during Early Follicular and Ovulation Phases in Healthy Women, Using Simple, Clinical Tests: A Cross Sectional Study. *Gynecological Endocrinology*, 35, 257-260. <https://doi.org/10.1080/09513590.2018.1519788>

- Federation Internationale de Gymnastique (2025). *Trampoline*.  
<https://www.gymnastics.sport/site/rules/#7>
- Ferger, K., Hackbarth, M., Mylo, M. D., Müller, C., & Zentgraf, K. (2019). Measuring Temporal and Spatial Accuracy in Trampolining. *Sports Engineering*, 22, Article No. 18.  
<https://doi.org/10.1007/s12283-019-0310-9>
- Heinen, T., & Krepela, F. (2016). Evaluating Routines in Trampoline Gymnastics. *Science of Gymnastics Journal*, 8, 229-238. <https://doi.org/10.52165/sgj.8.3.229-238>
- Itaya, A. (2015). Feedback System for Sensory and Postural Control. *Journal of Biomechanics*, 39, 197-203.
- Ito, N., Yamazaki, H., Hirai, T., Suzuki, M., Miyamoto, E. et al. (2000). Kinematics on Straight Jump in Trampoline. *Bull of Nippon Sport Science University*, 30, 59-64.
- Izumi, T. (2018). Report on Trampoline Competitions that Involved in as Physical Coach: Physical Training Strengthening Plan for National Team. *NSCA Japan*, 25, 26-30.
- Lee, B. J., Cho, K. H., & Lee, W. H. (2017). The Effects of the Menstrual Cycle on the Static Balance in Healthy Young Women. *Journal of Physical Therapy Science*, 29, 1964-1966.  
<https://doi.org/10.1589/jpts.29.1964>
- Matsushima, M., & Yano, S. (2018). Difference between Trampoline and Rebound Jumps during the Down Phase. *Exercise and Sports Science*, 23, 133-138.
- Qian, J., Mao, Y., Tang, X., Li, Z., Wen, C., & Zhang, S. (2020). A Finite Element Model for Estimation of Contact Dynamics during a Jumping Movement on a Trampoline. *Journal of Human Kinetics*, 73, 59-72. <https://doi.org/10.2478/hukin-2019-0127>
- Robert, S., & Amanda, B. (2019). *Fascia in Sport and Movement* (pp. 47-62). Round Flat.
- Shintani, S., Yamazaki, H., & Sugita, M. (2022). Strategic Differences in Trampoline Gymnastics between Japanese and World Athletes. *Taikugaku kenkyu (Japan Journal of Physical Education, Health and Sport Sciences)*, 67, 103-112.  
<https://doi.org/10.5432/jjpehss.21029>
- Takahashi, M., Bando, Y., & Fukui, T. (2023a). Effect of Skeletal Muscle Mass and Occlusal State on Flight Time of Straight Jumps in Trampoline Competition. *Dental Research and Oral Health*, 6, 52-57. <https://doi.org/10.26502/droh.0062>
- Takahashi, M., Bando, Y., & Fukui, T. (2024a). Influence of Hip Joint Range of Motion on Postural Stability in Trampoline Gymnasts. *Dental Research and Oral Health*, 7, 74-79.  
<https://doi.org/10.26502/droh.0078>
- Takahashi, M., Bando, Y., Fukui, T., & Sugita, M. (2024b). Light Clenching Differentially Affects Balance Ability According to Occlusal Contact Stability. *Applied Sciences*, 14, Article 10314. <https://doi.org/10.3390/app142210314>
- Takahashi, M., Bando, Y., Fukui, T., Maruyama, A., & Sugita, M. (2023c). Equalization of the Occlusal State by Wearing a Mouthguard Contributes to Improving Postural Control Function. *Applied Sciences*, 13, Article 4342. <https://doi.org/10.3390/app13074342>
- Takahashi, M., Bando, Y., Fukui, T., Maruyama, A., & Sugita, M. (2023d). Influence of Occlusion on Flight Time in Trampoline Competition. *International Journal of Dentistry and Oral Health*, 9, Article 405. <https://doi.org/10.16966/2378-7090.405>
- Takahashi, M., Bando, Y., Fukui, T., Maruyama, A., & Sugita, M. (2023e). Straight Jump Landing Position of Trampoline Gymnasts with Stable Occlusal Balance Reflects Standing Postural Control Function. *Applied Sciences*, 13, Article 6689.  
<https://doi.org/10.3390/app13116689>
- Takahashi, M., Bando, Y., Kitaoka, K., & Hata, K. (2023b). Effect of Wearing a Mouthguard

on Physical Ability Is Dependent on Occlusal Contact State: A Study Involving Elite Level Female Handball Players. *Dental Research and Oral Health*, 6, 88-94.

<https://doi.org/10.26502/droh.0066>

Takei, H. (2013). Posture Assessment and Treatment Approach. *Spinal Surgery*, 27, 119-124.

Thomas, W. M. (2016). *Anatomy Trains* (3rd ed., pp. 81-146, 201-227). Igaku-Shoin.

Uchiyama, Y. (1995). Postural Regulation. *Rigakuryoho Kagaku*, 10, 221-231.

<https://doi.org/10.1589/rika.10.221>