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Research Article

JOURNAL OF SPINE RESEARCH AND SURGERY

ISSN: 2687-8046

# Effect of occlusion on range of motion of spinal alignment during trunk flexion varies depending on exercise habits

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## Abstract

The purpose of this study was to clarify the differences in the effects of occlusion on the range of motion of spinal alignment during trunk flexion based on the participants' exercise habits. Participants were 16 healthy men, 14 trampoline gymnasts and 15 rugby players. Using a spinal shape analyzer, the lumbar range of motion, hip joint range of motion (HJM), and spinal range of motion (SM) during trunk flexion were measured. Differences in the range of motion of spinal alignment due to participant group and occlusion condition were analyzed using two-way ANOVA. In addition, the difference in the reduction rate in range of motion for each alignment due to clenching was analyzed using the Friedman test. Differences in the range of motion of spinal alignment among participants were noted in all measurement items, with the trampoline gymnasts showing the highest values regardless of occlusion conditions. Differences due to occlusal conditions were observed at all levels except for the SM in healthy men, and the range of motion of spinal alignment was greater when the mandibular rest position than when the clenching. The reduction rate in HJM due to clenching in rugby players was significantly greater than that of SM. The results of this study showed that the effect of occlusion on spinal alignment range of motion during trunk flexion exercise was greater in participants with exercise habits, and trunk stabilization was more pronounced. Furthermore, it became clear that rugby players tend to rely on hip joint movement during trunk flexion.

**Keywords:** Spinal alignment; Lumbar range of motion; Hip joint range of motion; Spinal range of motion; Trunk flexion; Occlusion; Clenching; Exercise habits; Trampoline gymnast; Rugby player

## Introduction

Postural stability is maintained by the continuous activity and tension of antigravity muscles, mainly in the front and back of the body [1-3]. When maintaining static standing posture, the activity of antigravity muscles is minimal, and fascial tension is primarily responsible for maintaining posture [1,2]. The antigravity muscles that make up the trunk play a role in postural stability during movements involving trunk flexion or extension [3]. Some of the deep muscles that make up the trunk are connected via myofascial connections to the jaw and neck muscles that contract when biting or clenching the teeth [4,5]. Specifically, the masseter, temporalis, and medial pterygoid muscles belong to the deep front line, and the sternocleidomastoid muscle belongs to the lateral line and superficial front line; all of these muscles contribute to stabilizing the body. The main sensory inputs for postural control are vision, somatosensation, and vestibular sensation. The periodontal

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**Citation:** Mutsumi Takahashi, Yogetsu Bando, Takuya Fukui. Effect of occlusion on range of motion of spinal alignment during trunk flexion varies depending on exercise habits. Journal of Spine Research and Surgery. 7 (2025): 85-90.

**Received:** August 01, 2025
**Accepted:** August 11, 2025
**Published:** August 18, 2025

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DOI:10.26502/fjsrs0092

ligament sensation associated with biting and clenching as well as the proprioception of the temporomandibular joint belong to the somatosensory inputs [6]. In addition, it has been reported that stimulation from biting and clenching increases the sensitivity of vestibular sensory input [7,8]. From these findings, it can be inferred that occlusion affects postural stability and the spinal movement associated with flexion and extension of the trunk.

Spinal alignment is formed along with the development of standing postural control and tends to be modified by environmental factors such as lifestyle and work posture [9,10]. Spinal movement during forward trunk bending is influenced by the activity of the back and abdominal muscles [11,12], and the antigravity muscles are responsible for controlling the standing position against forward leaning as well as increase the sensitivity of somatosensory input in postural control [13,14]. We previously investigated the relationship between occlusion or clenching and spinal alignment and revealed the following: 1) teeth clenching does not affect spinal alignment in the static standing position, but it does affect trunk flexion posture [6]; and 2) individuals with good occlusal contact can exert a greater effect on trunk stabilization through clenching [15].

The purpose of this study was to clarify the differences in the effects of occlusion on the range of motion of spinal alignment during trunk flexion exercise based on the participants' exercise habits. The null hypothesis was that the range of motion of spinal alignment was not affected by participants' exercise habits and occlusion.

## Materials and Methods

### Participants

Participants were men with no morphological or functional abnormalities in the stomatognathic system and normal occlusion. Exclusion criteria were tooth defects other than in the wisdom teeth, ongoing dental treatment, presence of musculoskeletal pain or severe low back pain within the past 12 months, or a history of surgery in the lower limbs, spine, or pelvis [6]. Participants who satisfied these criteria were 16 healthy men (age, 21.8±1.6 years), 14 trampoline gymnasts (age, 19.7±1.4 years) and 15 rugby players (age, 19.3±1.1 years). The exercise habits of the trampoline gymnasts and rugby players included training 6 or more times a week.

This study was approved by the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (ECNG-R-443). The details of the study were explained in full to all participants and proxies, and their informed consent was obtained.

### Measurement of spinal alignment

Spinal alignment was measured using a spinal shape analyzer (Spinal Mouse; Index Ltd., Tokyo, Japan) [6,16,17]. The baseline of the Spinal Mouse was aligned with the seventh cervical vertebra and moved along the paravertebral line to the third sacral vertebra to measure the lumbar lordosis angle, sacral slope angle, and spinal inclination angle (Figure 1). Measurements were performed in a static standing position as well as in a standing forward bending position (Figure 2). The lumbar range of motion (LM), hip joint range of motion (HJM), and spinal range of motion (SM) were calculated from the two measurements, using the software of the spinal shape analyzer. The measurement conditions were mandibular rest position and clenching in intercuspal position. Each measurement was performed for about 5 s with a rest interval of 1 min.

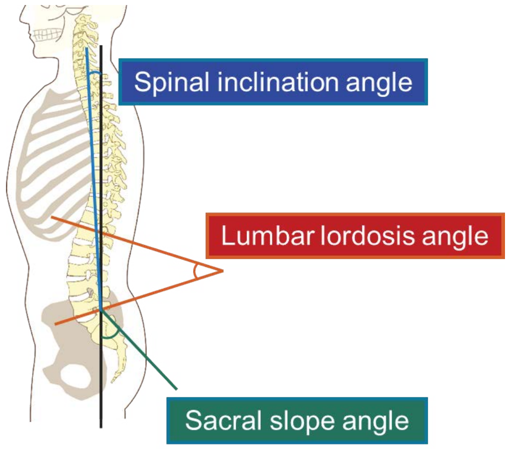


**Figure 1:** Each spine alignment used as an evaluation index.

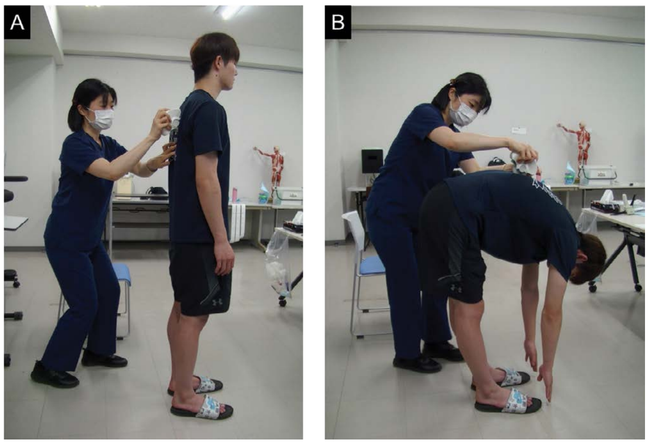


**Figure 2:** Measurement of spinal alignment. A; upright position, B; forward bending position.

### Statistical analysis

Statistical analysis was performed using SPSS ver. 17.0 (SPSS Japan Inc., Tokyo, Japan), and a P-value below 0.05 was considered significant. The Shapiro–Wilk test was used to examine the normality of distribution and Levene's test was used to examine the homogeneity of variance.

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The range of motion for spinal alignment in each participant group was confirmed to be normal and homogeneous at all levels. Accordingly, a two-way analysis of variance was performed to examine differences due to participant group and occlusion condition. The rate of reduction in range of motion for each spinal alignment due to clenching did not exhibit normality for the levels of SM in healthy men or LM in rugby players, so analysis was performed using the Friedman test. For factors that were significant, multiple comparison tests between levels were conducted using the Bonferroni method.

## Results

Table 1 shows the results of two-way analysis of variance on the range of motion of spinal alignment by participant group and occlusal condition. For each analysis item—LM, HJM, and SM—the factors of participant group and occlusal condition were significant (P<0.01, P<0.05), but no interactions were observed.

**Table 1:** Results of two-way analysis of variance for the range of motion of spinal alignment by participant group and occlusal condition.

| Source | *df* | SS | MS | *F* value | *P* value |
|---|---|---|---|---|---|
| Lumbar range of motion | | | | | |
| Participant group (A) | 2 | 2131.937 | 1065.968 | 16.183 | <0.001** |
| Occlusal condition (B) | 1 | 623.661 | 623.661 | 9.468 | 0.003** |
| A*B | 2 | 23.177 | 11.589 | 0.176 | 0.839 |
| Error | 84 | 5533.197 | 65.871 | | |
| | | | | | |
| Hip joint range of motion | | | | | |
| Participant group (A) | 2 | 667.334 | 333.667 | 11.389 | <0.001** |
| Occlusal condition (B) | 1 | 288.72 | 288.72 | 9.854 | 0.002** |
| A*B | 2 | 23.652 | 11.826 | 0.404 | 0.669 |
| Error | 84 | 2461.058 | 29.298 | | |
| | | | | | |
| Spinal range of motion | | | | | |
| Participant group (A) | 2 | 4062.317 | 2031.158 | 18.996 | <0.001** |
| Occlusal condition (B) | 1 | 434.726 | 434.726 | 4.066 | 0.047* |
| A*B | 2 | 36.635 | 18.317 | 0.171 | 0.171 |
| Error | 84 | 8981.76 | 106.926 | | |

*df*: degree of freedom. SS: sum of squares. MS: mean square.

***P*<0.01, **P*<0.05: denotes statistically significant difference.

Figure 3 shows the results of multiple comparison tests for LM depending on the participants and occlusal conditions. Significant differences among participant groups were observed between healthy males and trampoline gymnasts (P<0.01) and between healthy males and rugby players (P<0.05) in the mandibular rest position condition. A significant difference in the clenching condition was observed between healthy males and trampoline gymnasts (P<0.05). The range of motion was greatest in trampoline gymnasts, followed by rugby players and healthy males (P<0.01, P<0.05). In all participant groups, the clenching condition showed significantly lower values compared with the mandibular rest position condition (P<0.01, P<0.05).

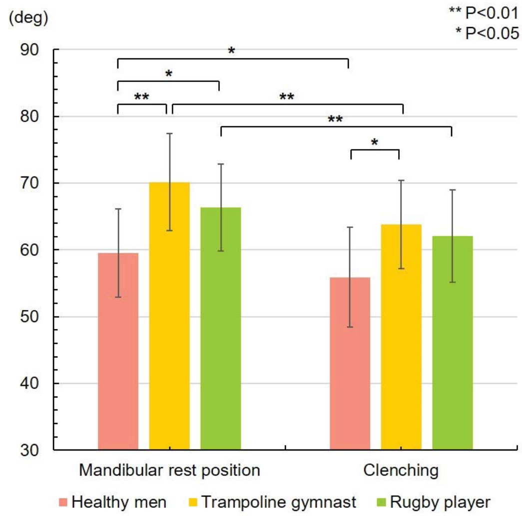


**Figure 3:** Differences in lumbar range of motion depending on participant groups and occlusal conditions.

Figure 4 shows the results of multiple comparison tests for HJM depending on participants and occlusal conditions. Differences among participant groups were observed between healthy males and trampoline gymnasts (P<0.01) and between trampoline gymnasts and rugby players (P<0.01) in the mandibular rest position condition, and between trampoline gymnasts and rugby players (P<0.05) in the clenching condition. In all participant groups, the clenching condition showed significantly lower values compared with the mandibular rest position condition (P<0.01, P<0.05).

Figure 5 shows the results of multiple comparison tests for SM. Differences among participant groups were observed in the mandibular rest position condition between trampoline gymnasts and healthy males (P<0.05) and between trampoline gymnasts and rugby players (P<0.01). A significant difference in the clenching condition was found between trampoline gymnasts and the rugby players, with trampoline gymnasts showing significantly higher values (P<0.01). Differences due to occlusal conditions were observed in both trampoline gymnasts and rugby players, with the clenching condition

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showing significantly lower values compared with the mandibular rest position condition (P<0.01).

Figure 6 shows a comparison of the rate of reduction in the range of motion for each spinal alignment due to clenching. No significant differences were observed in the rate of reduction in range of motion for each alignment between participant groups. Differences in the rate of reduction in range of motion for each spinal alignment were observed only in rugby players, and the rate of reduction in HJM was significantly greater than the rate of reduction in SM (P<0.05).

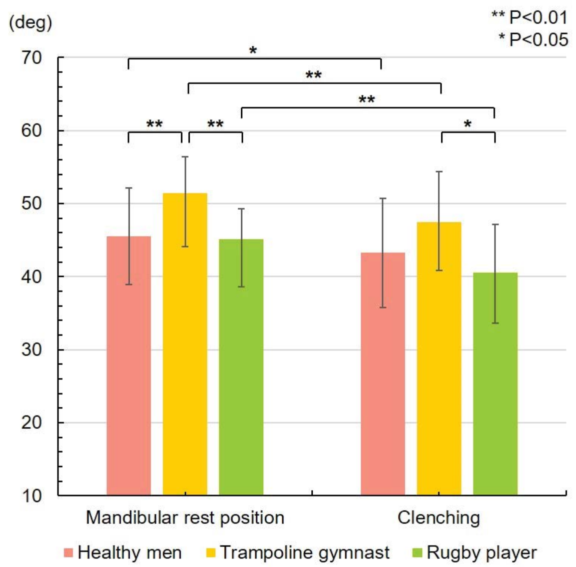


**Figure 4:** Differences in hip joint range of motion depending on participant groups and occlusal conditions.

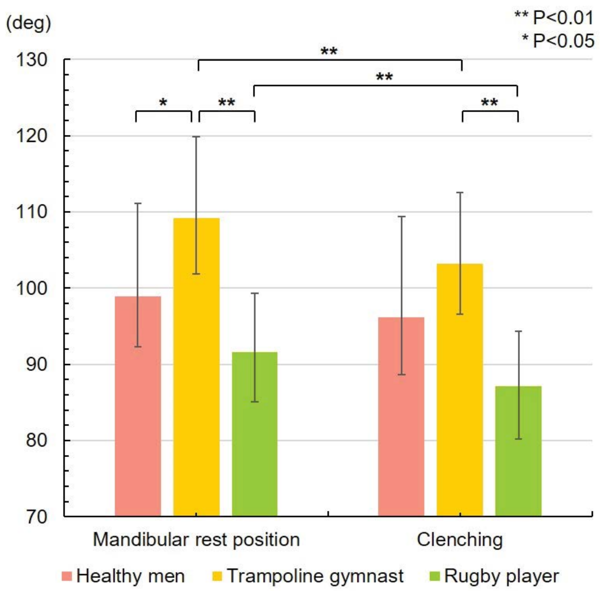


**Figure 5:** Differences in spinal range of motion depending on participant groups and occlusal conditions.

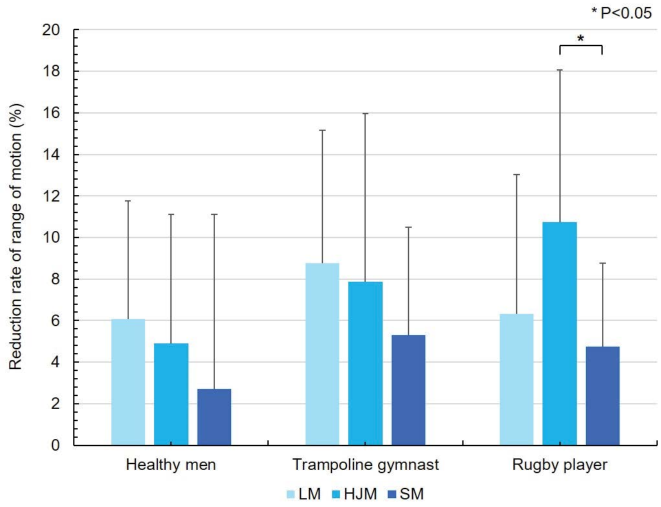


**Figure 6:** Comparison of reduction rates of spinal alignment range of motion due to clenching. LM; lumbar range of motion, HJM; hip joint range of motion, SM; spinal range of motion.

## Discussion

The results of this study showed that the range of motion of spinal alignment was affected by participant groups and occlusal conditions. Therefore, the null hypothesis was rejected.

Regarding the influence of occlusion on the range of motion of spinal alignment, previous studies have revealed that the left–right balance of occlusal contacts and the improvement of occlusal contacts by wearing oral appliances have an effect [6,15]. In other words, when the occlusal contacts were well balanced, clenching had a greater effect on the range of motion of the spinal alignment than when the occlusal contacts were unbalanced. For this reason, the occlusal contact state of the participants in the present study was checked in advance using a pressure-sensitive film (Dental Prescale, 50H-R type) and an analysis device (OCCLUZER, FPD-709), and participants with a difference in occlusal contact area between the left and right sides of 10% or more (i.e., an imbalance in the occlusal contact state) were excluded from the study. The influence of occlusal contacts associated with clenching conditions on the measurement values was eliminated accordingly. Furthermore, a characteristic of spinal alignment is that the movement of the thoracic spine is restricted by the costovertebral and sternocostal joints adjacent to the thoracic facet joints [18]. Therefore, it is assumed that the influence of the surrounding muscles or fascia on the curvature of the thoracic spine during trunk flexion is very small. Previous studies have shown that thoracic spine range of motion is not affected by occlusion [6,15], and thus it was excluded from the measurements performed in the present study.

The results of this study showed that the range of motion in spinal alignment differed significantly among the participant groups, with trampoline gymnasts showing the greatest

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range of motion. Trampolining is a type of gymnastics that emphasizes flexibility, and the participants in this study had an average competitive experience of 11.8 years, meaning they have undergone extensive training since a young age, with a focus on balance and flexibility. Because spinal alignment is affected by environmental factors [9,10], it is surmised that the results of this study reflect the effects of their training and the characteristics of their sport. Trampoline competition is an event in which competitors perform acrobatic maneuvers involving rotations and twists while suspended in the air, and the airborne posture and take-off action greatly affect the score. In other words, because trunk stability and flexibility are directly linked to performance ability, it is believed that the range of motion in spinal alignment was greater than that of other participant groups. Meanwhile, no significant differences were observed between rugby players and healthy males, except in LM. A characteristic of rugby players' body shapes is the extremely large muscle volume from the neck to the shoulders and from the buttocks to the thighs. Because the range of motion of spinal alignment is affected by the flexibility of the surrounding muscles, it is surmised that the muscle mass and flexibility of rugby players influenced their HJM, which was significantly smaller than that of trampoline gymnasts.

The spinal shape analyzer used in this study enables reference of the average values for each alignment according to gender and age, and the average values for LM, HJM, and SM were 65°, 47°, and 103°, respectively. The results of this study showed that the range of motion for each alignment was greater than the average, but only for trampoline gymnasts, regardless of the mandibular rest position condition or the clenching condition. Our previous studies have shown that clenching reduces the range of motion of spinal alignment, except for the thoracic spine [6,15], and the present study revealed a similar tendency. The main jaw and neck muscles active during clenching are the masseter, temporalis, and medial pterygoid muscles. These muscles belong to the deep front line and form fascial links with the trunk muscles, thereby contributing to the stabilization of the body [4,5]. Compared with other fascial chains, the deep front line has a three-dimensional structure extending from the front to the back of the body [4,5]. In other words, it lies deep within the body, passes through the front of the hip joint, pelvis, and lumbar vertebrae, providing support from the front. For this reason, it can be inferred that muscle tension might have a significant effect on trunk flexion, extension, and lateral bending. In other words, the range of motion of spinal alignment might be reduced by clenching as a result of the fascial chain of anatomical structures that are susceptible to clenching.

No differences were found between participant groups in the rate of reduction in range of motion for each spinal alignment due to clenching. From this, it can be inferred that the effect of clenching on trunk stabilization was consistent and not affected by the physical characteristics of the participants. However, the effect of clenching on each alignment was observed only in rugby players, and the rate of decrease in HJM tended to be significantly greater than the rate of decrease in SM. From this, it was inferred that trunk flexion in rugby players tends to be highly dependent on hip joint movement. However, the small number of participants in each group is a limitation of this study, and it will be necessary to validate the findings with a larger study population in the future.

## Conclusion

The results of this study showed that the effect of occlusion on the range of motion of spinal alignment during trunk flexion movements differed depending on the participants' exercise habits, and trunk stabilization through clenching was more pronounced in those with exercise habits. Furthermore, the range of motion of spinal alignment differed among participants, with trampoline gymnasts showing a tendency to have a greater lumbar range of motion compared with healthy males, and a greater hip joint range of motion than rugby players. In addition, it became clear that rugby players tend to rely on hip joint movement during trunk flexion.

## Data Availability

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

## Acknowledgments

This work was supported by JSPS KAKENHI Grant Number JP23K10617 and the Nippon Dental University Intramural Research Fund (NDU Grants N-21004).

## Conflicts of interest statement

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

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**Citation:** Mutsumi Takahashi, Yogetsu Bando, Takuya Fukui. Effect of occlusion on range of motion of spinal alignment during trunk flexion varies depending on exercise habits. Journal of Spine Research and Surgery. 7 (2025): 85-90.