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Influence of Hip Joint Range of Motion on Postural Stability in Trampoline Gymnasts

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Abstract

The aim of this study was to examine the effect of hip joint range of motion on dynamic stability, including the effect of occlusion. Participants were 13 male trampoline gymnasts. Spinal curvature was measured for each participant in the standing upright position, standing forward flexed, and standing extended positions using a spinal column shape analyzer, and the software calculated hip joint range of motion. Dynamic stability was evaluated by performing a cross-test with a center-of-gravity sway meter. The rectangular area obtained from the product of the longitudinal and transverse moving distances of the center of foot pressure in the center-of-gravity movement trajectory diagram was used as an index of dynamic stability. Measurements were performed under three conditions: mandibular rest position (RP), occlusion in intercuspal position (OP), and occlusion when wearing a mouthguard (MG). The hip joint range of motion or rectangular area under different occlusal conditions was compared using repeated measures ANOVA. Under each occlusal condition, Pearson's product–moment correlation coefficient was used to analyze the correlation between two variables. The hip joint range of motion and rectangular area were lowest in the OP, with significant differences observed between OP and RP and between OP and MG ($P<0.05$). A positive correlation was found between the two under all conditions ($P<0.05$). This study suggested that greater hip joint range of motion was associated with greater dynamic stability. Furthermore, it suggests that hip joint range of motion may be influenced by the balance of occlusal contacts.

Keywords: Hip joint range of motion; Dynamic balance; Posture stability; Occlusion; Mouthguard

Introduction

Postural stability can be divided into two types: static stability and dynamic stability. Static stability is the control of posture that keeps the center of gravity within the base of support in a fixed place, whereas dynamic stability is the control of posture that resists external forces and maintains the intended state when the base of support or center of gravity changes in an unstable environment [1]. Smooth shifting of the center of gravity is achieved through flexibility of the hip joint, flexibility of deep joint muscles such as the iliopsoas and obturator internus and externus, and spinal movement in conjunction with the lumbar vertebrae. The range of motion of the hip joint consists of six movements: flexion, extension, adduction, abduction, internal rotation, and external rotation. In daily life, these movements are compounded, allowing the hip joint to assume various positions. When the range of motion of the hip joint is limited, the pelvis tilts forward and the lumbar vertebrae

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compensate for that movement. Furthermore, because the linkage with the ankle joints cannot be utilized when moving the center of gravity, excessive loads are placed on the joints and ligaments of the ankles and knees. We previously investigated the effects of clenching on spinal movement and found that voluntary clenching reduces the range of motion of the lumbar and sacrum, supporting trunk stabilization [2]. When using a spinal column shape analyzer (Spinal Mouse), the sacral inclination angle reflects pelvic inclination, and the measurement result when the knee joint is extended corresponds to the movement of the associated hip joint [2,3]. This allows the range of motion of the hip joint to be objectively evaluated.

Dynamic sports involve various special movements and repeated postural changes that do not occur in everyday life. Predictive and reflexive postural control play a major role in maintaining posture during competition [4,5]. Postural adjustment at this time involves sensory input from vision, vestibular sensation, and somatic sensation [6,7], and clenching or occlusion is a factor that affects vestibular sensation and somatic sensation [3,8]. We have previously investigated the effect of occlusion on postural control function and found that the condition of occlusal contacts affects static balance, that the effect of the condition of occlusal contacts on static balance differs depending on the type of sport, and that correcting the condition of occlusal contacts by wearing an intraoral appliance improves static balance [9-11].

The purpose of the present study was to examine the effect of hip joint range of motion on dynamic stability, including the effect of occlusion. The null hypothesis was that the range of motion of the hip joint is not affected by dynamic stability and that no differences are observed due to occlusal conditions.

Materials and Methods

Participants

Participants were 13 male trampoline gymnasts (mean age 17.8 ± 2.2 years) with normal occlusion and no subjective or objective morphological or functional abnormalities in the oral-maxillofacial system. The participants had an average athletic history of 11.8 ± 2.6 years and trained 3 hours per day, 6 times per week.

This study was approved by the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (approval no. ECNG-R-443). The details of the study were fully explained to all participants and written informed consent was obtained prior to participation.

Mouthguard fabrication

A single-layer mouthguard was fabricated using a 2.0 mm thick thermoplastic sheet (Sports Mouthguard; Keystone Industries, Cherry Hill, NJ) and a pressure-molding machine (Model Capture Try; Shofu Inc., Kyoto, Japan). After removal and polishing of excess material, the mouthguard was placed in the participant's mouth and adjusted so that all teeth were in even contact with each other with light clenching. The amount of occlusal elevation due to mouthguard thickness was set within the range of the resting space [9,12,13].

Measurement of hip joint range of motion

Spinal curvature was measured for each participant in the standing upright position, standing forward flexed, and standing extended positions using a spinal column shape analyzer (Spinal Mouse; Index Ltd., Tokyo, Japan) [2,3]. The baseline of the measurement device was set at the seventh cervical vertebra (C7) and moved along the paraspinal line to the third sacral vertebra (S3), where the relative position of each vertebra and the distance and angle between the vertebrae were recorded [14,15]. Thoracic kyphosis angle, lumbar lordosis angle, sacral slope angle, and their respective ranges of motion were calculated using the Spinal Mouse software. In this study, the range of motion of the sacral slope angle from forward flexion to extension was defined as the hip range of motion. Measurements were performed under three conditions: mandibular rest position (RP), occlusion in intercuspal position (OP), and occlusion when wearing a mouthguard (MG). Each measurement lasted approximately 5 s, with a 1-min interval between each measurement.

Measurement of dynamic stability

Dynamic stability was evaluated by performing a cross test with a center-of-gravity sway meter (GRAVICORDER GS-7; Anima Co., Tokyo, Japan). Participants were instructed to stand upright with the inside of both feet 5 cm away from the reference point on the measurement table. With the static standing position as the reference position, participants were instructed to slowly move their upper body forward, to the reference position, backward, to the reference position, to the left, to the reference position, to the right, and back to the reference position, taking 3 s for each movement [16]. Participants were instructed not to allow their heels to float off the measuring table during these movements. Each measurement lasted 30 s. The measurement conditions were the same as those for measuring the hip joint range of motion: RP, OP, and MG. The rectangular area obtained from the product of the longitudinal and transverse moving distances of the center of foot pressure (COP) in the center-of-gravity movement trajectory diagram was used as an index of dynamic stability (Figure 1) [16].

Statistical analysis

Statistical analysis was performed using SPSS ver. 17.0 (SPSS Japan Inc., Tokyo, Japan) and the level of significance was set at $P<0.05$. The Shapiro–Wilk test was used to test for normality, and normality was found at all levels.

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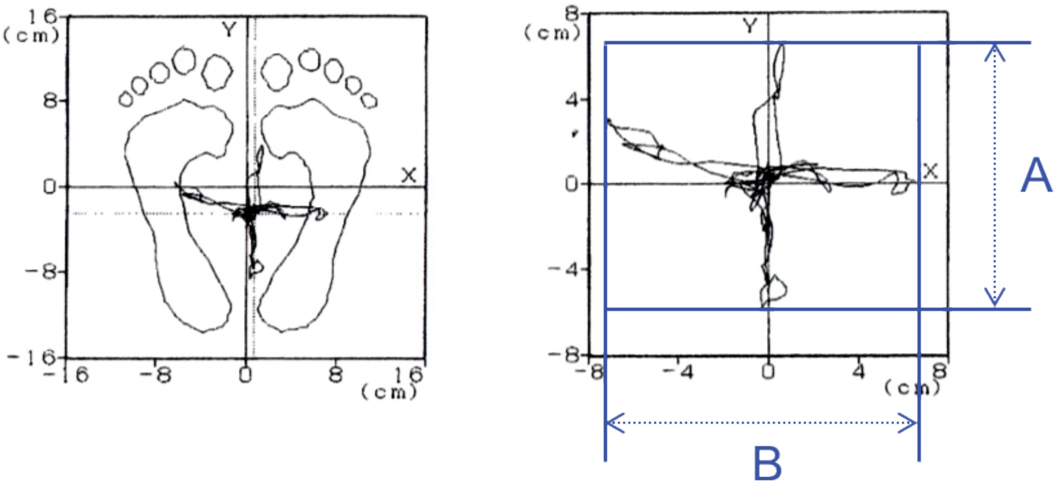

Figure 1: Example center-of-gravity trajectory diagram obtained by cross test. A: Anteroposterior movement distance of center of foot pressure, B: Left and right movement distance of center of foot pressure.

From the result of Mauchly's sphericity test, homoscedasticity was guaranteed for hip joint range of motion and rectangular area under each occlusal condition. For this reason, the hip joint range of motion or rectangular area under different occlusal conditions was compared using repeated measures ANOVA. Subsequently, multiple comparison tests between levels were performed using the Bonferroni method.

Next, Pearson's product–moment correlation coefficient was used to analyze the correlation between hip joint range of motion and rectangular area under each occlusal condition.

Results

Figure 2 shows the results of the multiple comparison test on the differences in hip joint range of motion according to occlusal conditions. Hip joint range of motion decreased in the order of RP, MG, and OP, with significant differences between RP and OP and between OP and MG (P<0.05). No significant difference was found between RP and MG.

Figure 3 shows the results of the multiple comparison test on the difference in rectangular area due to occlusal conditions. RP, MG, and OP showed the lowest values in that order, and significant differences were observed between RP and OP as well as between OP and MG (P<0.05). No significant difference was observed between RP and MG.

Figure 4 shows the results of the correlation analysis between hip joint range of motion and rectangular area. A positive correlation was found between the two under all conditions, with the greater the hip joint range of motion, the greater the rectangular area (RP: R=0.562, P<0.05; OP: R=0.559, P<0.05; MG: R=0.557, P<0.05).

Discussion

The results of this study showed that the hip joint range of motion and dynamic stability differed depending on the

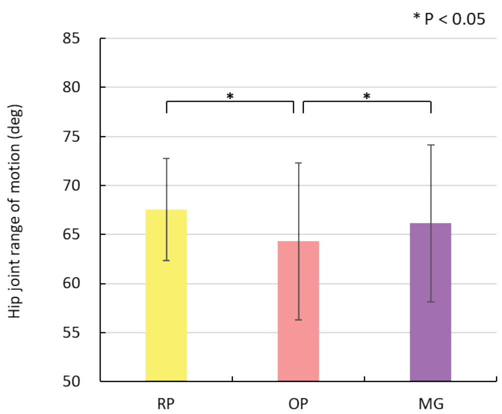

Figure 2: Differences in hip joint range of motion due to occlusal conditions. RP: Mandibular rest position, OP: Occlusion in intercuspal position, MG: Occlusion when wearing a mouthguard. *P<0.05: denotes statistically significant difference.

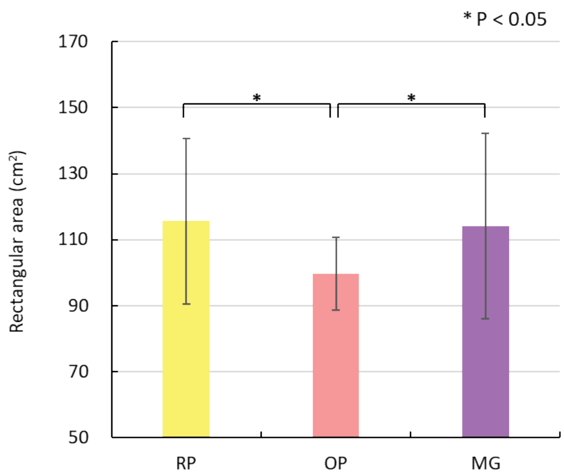

Figure 3: Differences in rectangular area due to occlusal conditions. RP: Mandibular rest position, OP: Occlusion in intercuspal position, MG: Occlusion when wearing a mouthguard.
*P<0.05: denotes statistically significant difference.

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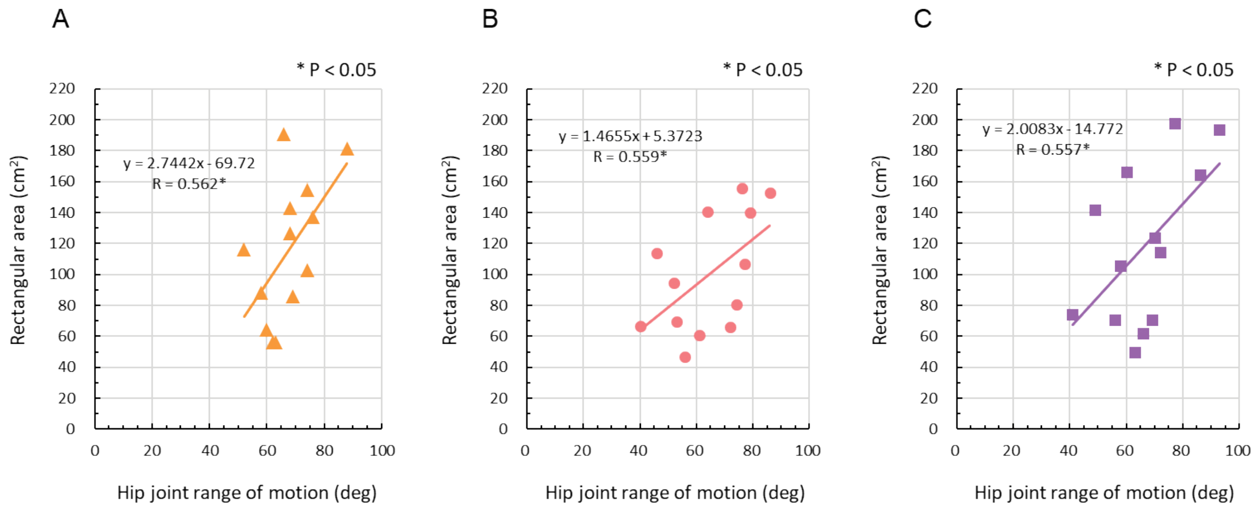

Figure 4: Correlation between hip joint range of motion and rectangular area. A: Mandibular rest position (RP), B: Occlusion in intercuspal position (OP), C: Occlusion when wearing a mouthguard (MG). *P<0.05: denotes statistically significant difference.

occlusal conditions, and a correlation was found between hip joint range of motion and dynamic stability under each occlusal condition. Therefore, the null hypothesis was rejected.

Trampoline gymnasts were selected as participants in this study for two main reasons. The first reason is that trampoline competition is a type of gymnastics, a sport in which postural stability and flexibility are directly related to competitive performance [17,18]. Participants in this study were athletes aged 15 to 21 years with an average competitive experience of 11.8 years, which was considered an appropriate selection for trampolinists. Second, previous research has shown that athletes who engage primarily in posture training have better postural stability than do athletes who engage primarily in strength training, and that the interventional effects tend to be more pronounced [9]. For these reasons, the results of this study can be applied to evaluate the physical condition of individual athletes and might become a useful tool for judging the effectiveness of training in the future.

The range of motion of a joint is generally measured using a dedicated measuring device (goniometer) [19,20]. In the present study, we chose a spinal shape analyzer because it can be used while the athlete is standing in an upright position, measurements can be performed in a short time of approximately 5 s, objective data can be obtained, and the reliability of such measurements has previously been confirmed [2,3,15].

There are multiple methods for evaluating dynamic stability, and they are selected depending on the participant's health condition, age, disease, or competition characteristics [16,21-23]. In the present study, a cross-test was performed with a center-of-gravity sway meter to measure COP displacement [16]. This method evaluates the movement of the center of gravity forward, backward, and side to side without bending the upper body, so hip joint movement is easily reflected in the measurements. In other words, if the range of motion of the hip joint is small, the distance traveled by the COP will also be smaller, and thus the rectangular area will also tend to be smaller. Furthermore, when hip joint movement is smooth, the COP trajectory diagram during upper body movement tends to show a clear cross shape [16]. In the present study, the rectangular area reflecting the COP movement distance was used as an index to evaluate the relationship with the hip joint range of motion.

Mouthguards are generally worn to prevent and reduce the severity of sports injuries, but in this study, they were used as intraoral devices to improve occlusal contact. It has been reported that the occlusal contact state affects postural stability and physical ability [10-13,24,25]. Changes in occlusal height can affect the sense of position of the temporomandibular joint and vestibular sensation in postural control. Therefore, the amount of occlusal elevation by the mouthguard in this study was kept to a minimum and adjusted to be within the range of the resting space. Furthermore, measurements under the MG condition were performed after confirming that the participants were accustomed to wearing the mouthguard and did not feel any pain or discomfort.

The results of this study showed that the range of motion of the hip joint estimated from the measurements of the sacrum range of motion using a spinal shape analyzer was affected by occlusal conditions. In other words, the range of motion of the hip joint was smaller when the participants occluded in the intercuspal position compared with the mandible resting position or when the mouthguard was worn. Our previous research on the effect of occlusion on spinal range of motion focused on handball players who had good left-right balance in occlusal contacts [2]. In that study, the

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sacral range of motion was significantly greater in RP than in OP and MG, and although MG showed higher values compared with OP, the differences were not significant. The disparity in results between the previous studies and the present study might have been influenced by the participants' occlusal contact conditions. When the occlusal contact state of the participants in this study was evaluated in advance using a pressure-sensitive film (Dental Prescale, 50H-R type; Fujifilm Co., Ltd., Tokyo) and the manufacturer's dedicated analysis device (Occluzer FPD-709; Fujifilm Co., Ltd.), the average value of the left–right difference in occlusal contact area was approximately 16.0%. That is, the participants in this study were a group in which many had poor occlusal contact conditions. The mouthguard used for occlusal correction was adjusted so that all teeth were in even contact with each other during light clenching. In addition, because the mouthguard has viscoelasticity, it can stabilize the jaw position regardless of the strength of clenching. It was suggested that these factors (i.e., the participant's occlusal contact condition, the occlusal contact condition of the mouthguard, and the physical properties of the mouthguard) might have influenced spinal movement that was more stable with MG than with OP.

The rectangular area, which was used as an index of dynamic stability, was affected by occlusal conditions, just like the hip joint range of motion, and OP showed lower values compared with RP and MG. It has been reported that people with good occlusal balance tend to have a more stable center of gravity compared with those with poor occlusal balance, and that wearing a mouthguard stabilizes the center of gravity for people with poor occlusal balance [9,12,26]. Therefore, similar to the differences in hip joint range of motion due to occlusal conditions, the differences in rectangular area due to occlusal conditions were likely influenced by the participants' occlusal contact conditions. In addition, the OP conditions of the participants in this study might have been a disturbing factor in dynamic stability. Therefore, the rectangular area was probably significantly larger under the occlusal correction condition (MG) than under OP.

A correlation analysis was performed between hip joint range of motion and rectangular area, and a significant positive correlation was found between the two under all occlusion conditions. Based on this, it may be possible to estimate the quality of the hip joint range of motion from the rectangular area obtained by the cross test. In this study, the only spinal movement measured using the spinal shape analyzer was forward bending and extension. However, in future studies, it may be possible to estimate hip joint movement in greater detail by evaluating spinal alignment in lateral bending and rotation postures.

The main limitation of this study was the small number of participants, which made it impossible to compare differences between those with good and poor occlusal contact conditions. By continuing to perform measurements over time, we would like to increase the number of participants and clarify the influence of occlusal contact status on postural stability and spinal motion. In addition, we also want to investigate the relationship between the values obtained in the cross-test and motor function.

Conclusion

In this study, the relationship between hip joint range of motion and dynamic stability was examined in trampolinists, including the influence of occlusal conditions. As a result, a positive correlation was found between hip joint range of motion and dynamic stability, with the greater the hip joint range of motion, the higher the dynamic stability. Additionally, the range of motion of the hip joint was greater when occlusion was corrected with a mouthguard than when the teeth were in the intercuspal position, suggesting that the range of motion of the hip joint may be affected by the balance of occlusal contacts.

Data availability

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

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Conflicts of interest statement

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

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