RELATIONSHIP BETWEEN JUMPING-MOTION AND MUSCLE ACTIVITY DURING SOMERSAULT IN TRAMPOLINE: A CASE STUDY

Masaharu Matsushima[1]

[1] Gakko Hojin Ohara Gakuen, Hyogo, Japan

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Abstract

This study investigated the relationship between jumping-motion and muscle activity during somersaults on a trampoline. Participants were 10 trampoline athletes (3 high-level and 7 middle-level). As for the protocol, the athletes performed a jump continuation of the tucked backward somersault (Back) and the tucked forward somersault with half twist (Barani) on a trampoline. It was measured using an electromyogram (EMG) and video analysis. The jump was defined as "100 ms before touch" 100 ms before the subject landing on the trampoline bed; "Touch" at the moment of landing; "Lowest" at the moment of going down, and "Take off" at the moment of taking off. They were defined as "Before touch phase" from "100 ms before touch" to "Touch"; as "Down phase" from "Touch" to "Lowest", and as "Upward phase" from "Lowest" to "Take off". As a result, the trunk inclination angles of both the high- and middle-level participants regarding the Back (middle-level 4.3±1.3°, high-level 7.0±2.4°) and the Barani (middle-level 9.2±1.7°, high-level 9.4±1.7°) during the Lowest phase were forward. There were no significant differences. The EMG amplitude of the rectus abdominis ($p < 0.05$) during the Upward phase and the erector spinae ($p < 0.01$) during the Before touch phase were significantly higher in the high-level group. The trunk was inclined by using the erector spinae as in the high-level between Before 100ms touch and Lowest. Stabilization of the trunk by the activity of the rectus abdominis was the efficient movement of the lower extremity during the Upward phase.

Keywords *trampoline, backward somersault, forward somersault with half twist, electromyogram, take-off.*

INTRODUCTION

Improving jumping performance leads to higher movements on the trampoline. This directly affects the gymnast's score in trampolining as it can contribute to the performance score for total flight time (2022-2024 Code of Points Trampoline Gymnastics, [CoPTG] 2021). Coaches use the phrase "contracting your muscle" for general instruction in a jumping-motion. (Obayashi,1998). However, there is little evidence as to which muscle contracts at what timing. Previous studies on the muscle activity of the jumping-motion in trampolining reported that muscle activity in the lower extremity was observed before and after landing (Matsushima, et al., 2017; Matsushima, & Yano, 2018a; Matsushima, & Yano, 2018b; Song, Yao, & Sun, 2011).

However, extensive previous research on muscle activity in the jumping-motion from the ground reported that the mechanism of muscular activation started with activity in the proximal muscles and then the distal muscles of the lower extremity (Arai, Ishikawa, & Ito, 2013; Fukashiro,1990; Mark L, 2018). One study suggested that the bi-articular muscle of the lower extremity related to the motion in the vertical jump is associated with cooperative muscular activity combining excitement and inhibition (Dennis, Melissa, & Meghan, 2016; Oshima, et al., 2005; Torikai, et al.,2003; Van Ingen Schenau, et al., 1985).

Despite progress in research using electromyogram (EMG) analysis of muscle activity in jumping movements from the ground, most jumping-motions on the trampoline have not been studied. There has been minimal progress in studies of somersault jumping-motions (Deborah, Eduardo, & Jorge, 2021; Mkaouer, et al., 2012). Therefore, the purpose of this study was to investigate the somersault jumping-motion in trampoline athletes of different levels using an electromyogram and video analysis.

METHODS

Ten trampoline athletes (3 “high-level” Japanese national team members and 7 “middle-level”) were recruited as participants. The high-level Japanese national team members constituted 1 male and 2 females (age 20.3±0.9 years, body mass 55.7±5.6 kg, height 165.5±6.0 cm, athletic career 12.7±3.9 age), and the middle-level constituted 4 males and 3 females (age 19.1±1.6 years, body mass 59.7±8.9 kg, height 163.1±6.9 cm, athletic career 5.9±2.1 age).

This study was conducted after obtaining approval from the Research Ethics Screening Committee of Mukogawa Women's University (Approval Number No, 13-52). Informed consent was obtained from the participants and their guardians prior to the study. Additionally, they gave their written consent.

The EUROTRAMP trampoline Premium 4 × 4, officially recognized by the International Gymnastics Federation, was used for the experiment. For the trial protocol, the participants performed 5 preliminary jumps from stillness at the standing position, followed by the tucked backward somersault (Back), then the tucked forward somersault with half twist (Barani). The Back and the Barani were repeated alternately 5 times each. Therefore, the participants performed 10 somersaults after the 5 preliminary jumps. The trial protocol was decided on base of the Code of Points for trampoline gymnastics (2022-2024 Code of Points Trampoline Gymnastics, [CoPTG] 2021). A trampoline athlete must perform 10 elements continuously. Since most athletes alternate between backward and forward somersaults, a continuous somersault method was adopted in the study.

Participants were instructed to jump as high as possible at maximum effort. Each experimental session started with a standardized warm-up protocol to ensure the participants performed the vertical jumps at maximum effort without any risk of injury.

After each experiment, the isometric maximal voluntary contraction (MVC) of each muscle was measured by the manual muscle testing (MMT) method (Hislop, & Montgomery, 2007).

The experimental setup was connected to a pressure sensor load cell (LUX-B-2KN-ID, Kyowa Electronics, Japan, 1000Hz sampling) between the spring and flame of the trampoline side center, and marked the participant’s landing point (Touch), the lowest point (Lowest), and the leg take-off point (Take-off) on the trampoline.

Eight muscles were measured in total: sternocleidomastoid (SCN), trapezius upper part (TR), rectus abdominis (RA), erector spine (L4 level) (ES), rectus femoris muscle (RF), biceps femoris long head (BF), tibialis anterior (TA), and gastrocnemius (GL). Wireless electrocardiographs were attached in reference to Aldo (Aldo, 2007). An electrocardiogram of each participant was recorded using a wireless electrocardiograph (multi-channel telemetering system WEB-7000, Nihon Kohden, Japan). The experiment derived EMGs with a 1000Hz sampling frequency. The date signal stored in the memory card was transferred and stored on a personal computer (PC).

Moreover, participants were recorded from the side while they performed jumping using a high-speed camera (EX-F1, CASIO, Japan). The camera was set up at a heigh of 5.550m equivalent to the trampoline bed, and at 1.155 m from the center of the trampoline bed. The light-emitting diode (LED) lamp projected light on the high-speed camera at a range that did not influence the jumping. All data were synchronized.

To synchronously record the EMG and the load cell signals, the signal of the LED lamp was recorded.

The coordinate axis in the two-dimensional motion analysis assumed the horizontal axis as the X-axis and the vertical axis as the Y-axis. The reference point and standard length of the calibration assumed both ends (4.280m) of the trampoline bed to be on the X-axis.

The jump was divided into four stages and three phases and analyzed accordingly (Figure 1). The four stages were defined as “100 ms before touch” - 100 ms before the subject’s landing on the trampoline bed; “Touch” at the moment of landing; “Lowest” at the moment of going down, and “Take off” at the moment of taking off. They were defined as “Before touch phase” from “100 ms before touch” to “Touch”; as “Down phase” from “Touch” to “Lowest”, and as “Upward phase” from “Lowest” to “Take off”.

The EMG data collected during each action were converted through a band-pass filter (20–500 Hz) and full-wave, rectified to the EMG amplitude of each jump per unit time. The data were normalized using the EMG amplitude (%MVC) measured for each muscle during the time in which the muscle exerted MVC.

The video recordings of the participants’ bodies were used to digitize the acromion, greater trochanter, knee joint fissure, lateral malleolus, calcaneus, and fifth head of metatarsal bone by using two-dimensional analysis software (Frame-DIAS IV, DKH, Japan).

The hip joint angle was defined as the angle formed by the line which connects the greater trochanter from the acromion and the line which connects the knee joint fissure from the greater trochanter. The knee joint angle was defined as the angle formed by the line which connects the knee joint fissure from the greater trochanter and the line which connects the lateral malleolus from the knee joint fissure. The ankle joint angle was defined as the angle formed by the line which connects the calcaneus from the lateral malleolus and the line which connects the fifth head of metatarsal bone from the calcaneus. Moreover, each joint angle was calculated using the anatomical position starting at 0°. As for the trunk inclination angle, it was defined as the angle formed by the line which connects the greater trochanter from the acromion, and the line which connects vertically upward from the greater trochanter (Figure 2). The trunk inclination angle was assumed positive (+) in forward inclination, and negative (−) in backward inclination. The data were analyzed using each joint and trunk inclination angle in the jump with the longest flight time.

The mean value and standard deviation were obtained for the activity level of each muscle, joint, and trunk inclination angle. The Mann–Whitney U test was used to analyze the data. In each case, the significance level was set at 0.05.

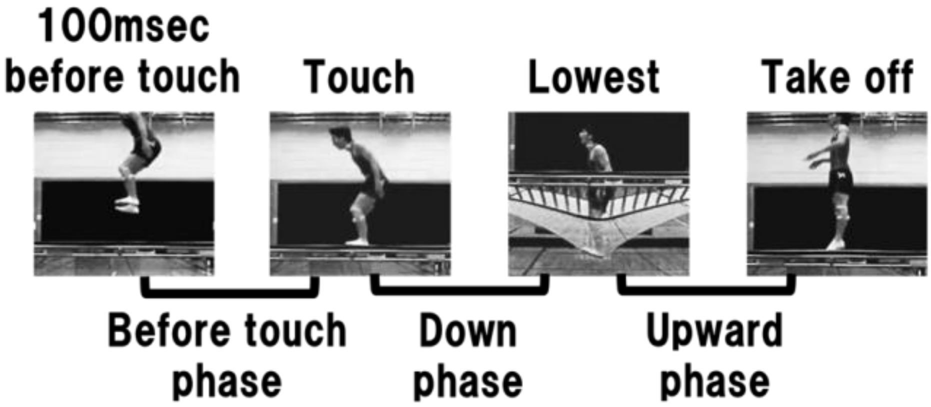

*Figure 1***.** Definition of the jump phase.

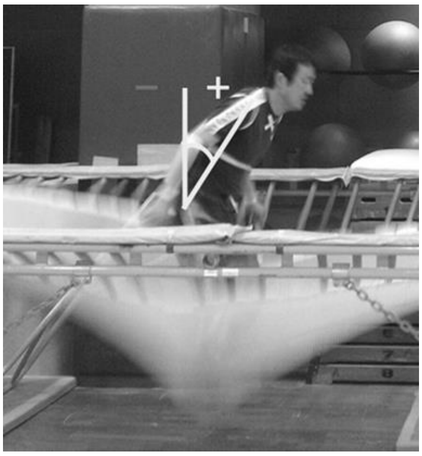

*Figure 2***.** Definition of trunk angle.

RESULTS

In the Back, the high-level participants were significantly higher than the middle-level participants in the ankle joint dorsiflexion angle during Before 100 ms of touch ($p < 0.01$), knee joint flexion angle during Before 100 ms of touch ($p < 0.05$), and hip joint flexion angle during Before 100 ms of touch ($p < 0.01$) and Lowest ($p < 0.05$) (Figure 3).

In the Barani, the high-level participants were significantly higher than the middle-level participants in the ankle joint dorsiflexion angle during Before 100 ms of touch ($p < 0.05$), knee joint flexion angle during Before 100 ms of touch, and Touch ($p < 0.01$), and hip joint flexion angle during Take-off ($p < 0.01$) (Figure 4).

In the Back, the change in the trunk inclination angle between Before 100ms touch and Lowest was significantly higher for the high-level participants (57.1±5.5°) than the middle-level (33.2±6.4°) ($p = 0.03$).

In the Barani, the change in the trunk inclination angle between Before 100ms touch and Lowest was higher in the high-level participants (44.1±2.5°) than the middle-level (28.8±6.8°), but there was no significant difference.

The trunk inclination angles of both levels in the Back (Middle-level 4.3±1.3°, high-level 7.0±2.4°) and the Barani (Middle-level 9.2±1.7°, high-level 9.4±1.7°) during Lowest were forward. There were no significant differences between the Back and the Barani.

The ES of EMG amplitude(%MVC) of the high-level participants was significantly higher than the middle-level ($p < 0.01$), and BF of the middle-level was recognized as significantly higher than the high-level ($p < 0.01$) during Before touch phase in the Back (Figure 5).

In the Back, the BF of EMG amplitude (%MVC) of the middle-level participants was significantly higher than the high-level during the Down phase ($p < 0.05$) (Figure 6).

In the Back, the BF of EMG amplitude (%MVC) of the middle-level participants was recognized as significantly higher than the high-level ($p < 0.01$) during the Upward phase (Figure 7).

In the Barani, the ES of EMG amplitude (%MVC) of the high-level participants was significantly higher than the middle-level, and BF of middle-level was significantly higher than the high-level ($p < 0.01$) during the Before touch phase (Figure 8).

In the Barani, the BF of EMG amplitude (%MVC) of the middle-level participants was significantly higher than the high-level ($p < 0.01$) during the Down phase (Figure 9).

In the Barani, the GL ($p < 0.01$) and RA ($p < 0.05$) of EMGs amplitude (%MVC) of the high-level participants was significantly higher than the middle-level, and BF of middle-level was significantly higher than high-level ($p < 0.01$) during the Upward phase (Figure 10).

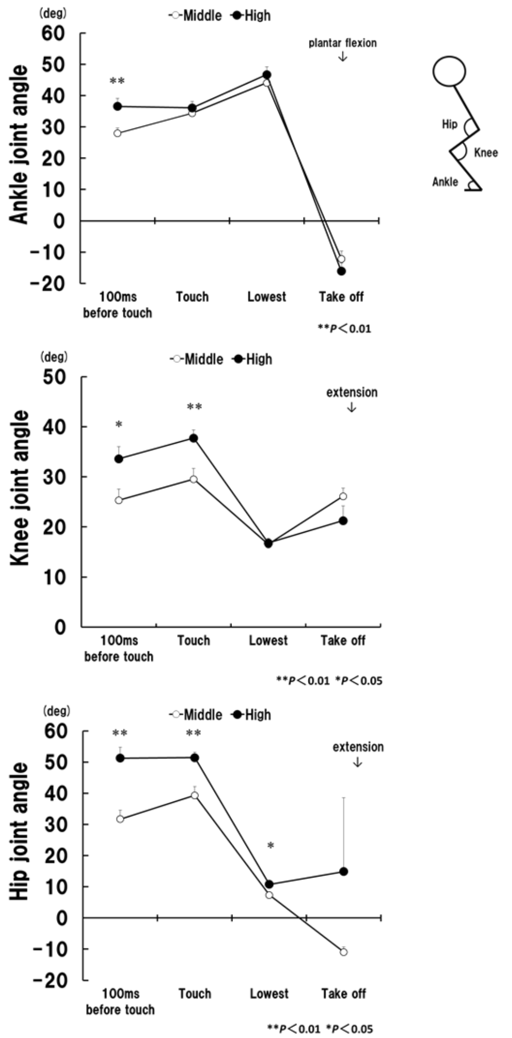

*Figure 3***.** Differences between the middle and high-levels in the leg joint angles of jump phases of the Back. Ankle, knee, and hip joint angles were shown from the top to bottom.

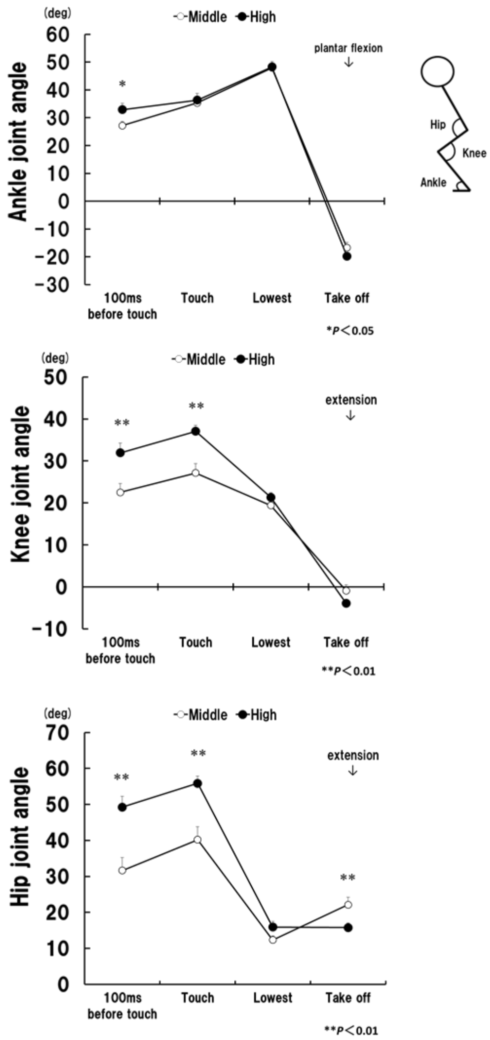

*Figure 4***.** Differences between the middle and high-levels in the leg joint angles of jump phases of the Barani. Ankle, knee, and hip joint angles were shown from the top.

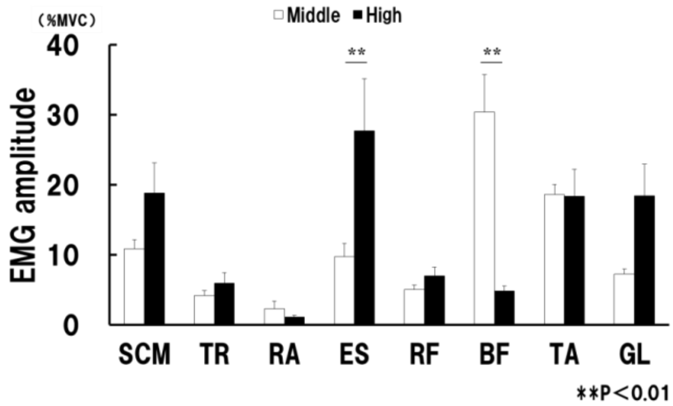

*Figure 5***.** Differences between the middle and high-level of EMGs amplitude (%MVC) during Before touch phase in the Back.

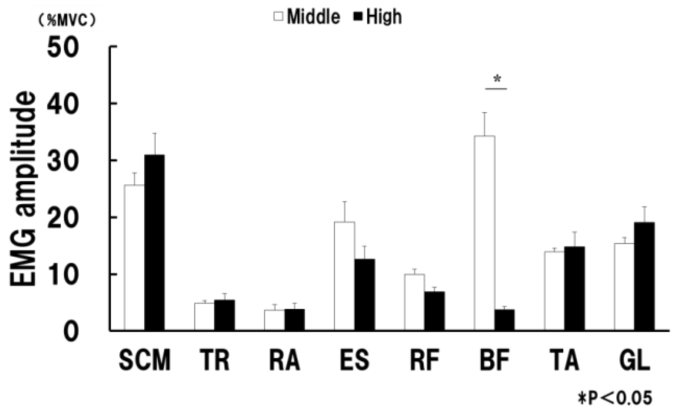

*Figure 6***.** Differences between the middle and high-level of EMGs amplitude (%MVC) during Down phase in the Back.

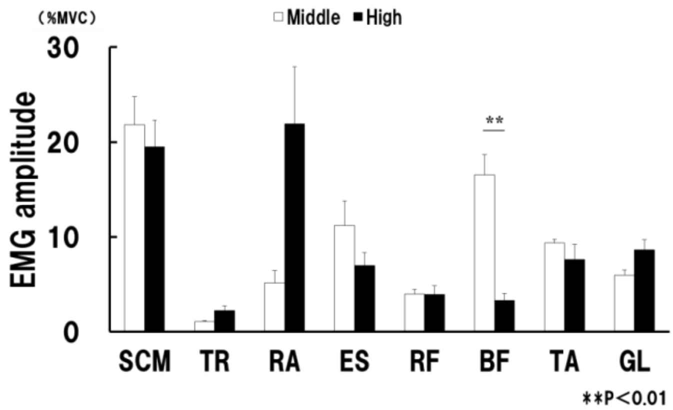

*Figure 7***.** Differences between the middle and high-level of EMGs amplitude (%MVC) during the Upward phase in the Back.

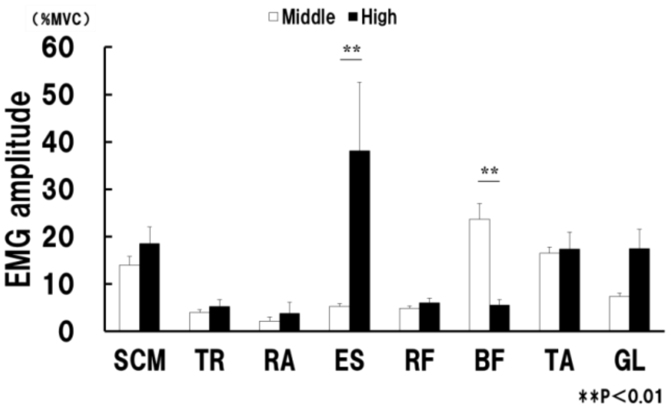

*Figure 8***.** Differences between the middle and high-level of EMGs amplitude (%MVC) during Before touch phase in the Barani.

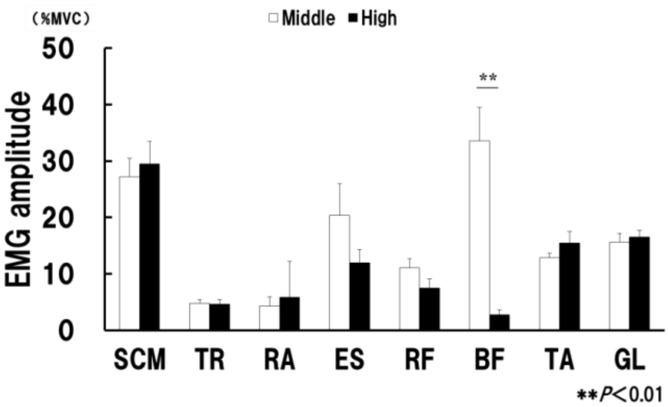

*Figure 9***.** Differences between the middle and high-level of EMGs amplitude (%MVC) during Down phase in the Barani.

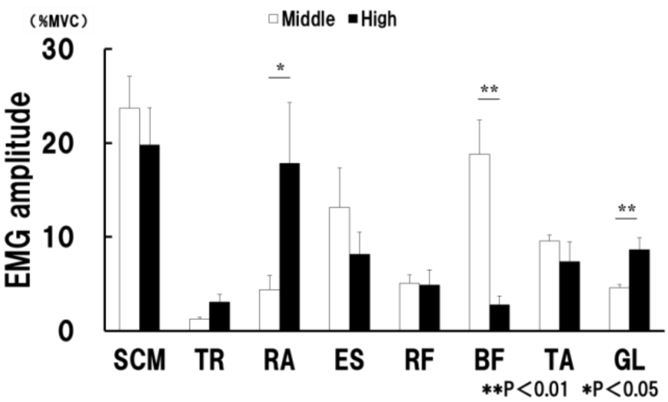

*Figure 10***.** Differences between the middle and high-level of EMGs amplitude (%MVC) during the Upward phase in the Barani.

DISCUSSION

The time of flight score signifies the total time the trampoline athlete stays in the air during a routine and is added to the score in all routines (2022-2024 Code of Points Trampoline Gymnastics, [CoPTG] 2021). The Back and the Barani are fundamental somersault jumps in routines (Dave, et al.,2015; Wojciech, & Adam, 2001). According to the results of this study, ES of EMG amplitude (%MVC) of both the Back and the Barani jumps was significantly higher in the high-level participants than in the middle-level group during the Upward phase (Figure 5, 8). In addition, the trunk was inclined backward so that even changes in the trunk inclination angle between Before 100ms touch and Lowest were evident. It was suggested that it was for the jumping-motion with the vertical posture. Therefore, the trunk in the vertical posture at Lowest was examined to see if it was controlled by using the backward trunk posture with activity of the ES.

At take-off, the knee joint angle was flexed in the Back, and the hip joint angle was extended in the Barani (Figure 3, 4). In previous studies, the knee and hip joint movements changed according to the somersault type (Dave, et al.,2015; Deborah, et al., 2021; Wojciech, & Adam, 2001). However, this study suggests that the RA of EMG amplitude (%MVC) of high-level participants is significantly higher during the Upward phase in both the Back and the Barani (Figure 7, 10). Since it is grounded on the trampoline, during a jumping-motion, movement of the lower extremity is a closed kinetic chain (CKC). However, it shifted gradually to an open kinetic chain (OKC) during the Take-off from the Lowest. Movement of the lower extremities in OKC requires a fixed trunk. According to Kondo and Iwata (Kondo, & Iwata, 2011), when the pelvis and lower extremities enable a certain movement, the trunk muscle activity can be activated. Therefore, although there are different motions of the lower extremities between the Back and the Barani, a significant activity of the RA in the high-level group showed that a trunk was stabilized and the lower extremity moved efficiently. The findings suggested that it was important in the jumping-motion of somersaults to ensure ES activity during the Before touch phase and RA activity during the Upward phase.

CONCLUSION

From the results, this study suggests that jumping-motion on a trampoline can improve. This study investigated the relationship between jumping-motion and muscle activity during a somersault in trampoline athletes.

The trunk was inclined by using the ES in the high-level athletes between Before 100ms touch and Lowest.

Stabilization of the trunk by activity in the RA was associated with efficient movement of the lower extremity during the Upward phase.

The participants performed somersault of the Back and the Barani in this study. In addition, the feedback recorded with the video camera provided a motion check since the aerial posture is reflected in one’s performance. However, the activity of muscles which could not be ascertained was the one factor that influenced performance in the video analysis. These results will be established with the instruction data for activating a specific muscle at suitable timing. These study findings should be further investigated to analyze various somersaults and twist motions in trampolining.

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Corresponding author:

Masaharu Matsushima, PhD
Gakko Hojin Ohara Gakuen,
Hyogo, Japan
61 Shiroganemati
Himeji-city, Japan
E-mail: m19832011@yahoo.co.jp

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