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ORIGINAL ARTICLE

Usefulness of a device for body support during operations performed while standing

Kiyoshi Ito[1] **· Tetsuyoshi Horiuchi**[1] **· Tatsuya Seguchi**[2] **· Kazuhiro Hongo**[1]

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Abstract During microsurgical procedures, manipulations are often performed using a foot switch while the surgeon stands on one foot. This position can easily result in body axis instability and greater musculoskeletal loading. To support the surgeon's posture, we have developed a tool called the "Surgeon's Body Support Device." The objective of this study was to determine the efficacy of this device by analyzing surgeons' kinematics and musculoskeletal loading during simulated operations undertaken while standing. Fourteen surgeons volunteered to perform simulations of surgery while standing. To analyze motion kinetics and musculoskeletal loading with and without this device, a three-axis accelerometer and surface electromyography (SEMG) sensors were attached to the subjects. Compared with not using the supportive device, the axis of the surgeon's body was significantly more stable when the support device was used (P=.001). The evenness of motion also tended to be superior when the device was utilized (P=.009). Simulations performed using the device significantly reduced the musculoskeletal loading on the ventral side of the left foot by 70 % compared with simulations performed not using the device (P=.001). Data from SEMG sensor placed on the right hand, which performs the surgical manipulations, indicated that simulations performed using the device generated approximately 10 % of the musculoskeletal load generated when the device was not used (P=.001). The Surgeon's Body Support Device appears to improve maneuverability and reduce musculoskeletal loading during simulated surgical procedures undertaken while standing.

Keywords Electromyography · Motion kinetics · Musculoskeletal loading · Standing operations · Surgeon's Body Support Device · Three-axis wireless accelerometer sensor

Introduction

Numerous microsurgical operations, including those performed on the spine, are conducted while standing. During operations performed while standing, the surgical instruments, including the operating microscope and the bipolar forceps, are controlled by the surgeon's foot. For example, microsurgical procedures often require meticulous hemostasis using bipolar forceps, and the microscope has to be focused and its field of view magnified. While using the foot switch, operators must stand on one foot, which can lead to the instability of the body axis and greater musculoskeletal loading. Consequently, operations undertaken while standing tend to be unstable compared with those undertaken while seated. We have developed a tool called the "Surgeon's Body Support Device" to support operators' bodies.

The objective of this study was to determine the efficacy of this new device by analyzing surgeons' kinematics and musculoskeletal loading during simulated operations performed while standing.

✉ Kiyoshi Ito
kitoh@shinshu-u.ac.jp

[1] Department of Neurosurgery, Shinshu University School of Medicine, 3-1-1 Asahi, Matsumoto 390-8621, Japan

[2] Seguchi Neurosurgical Hospital, Iida, Japan

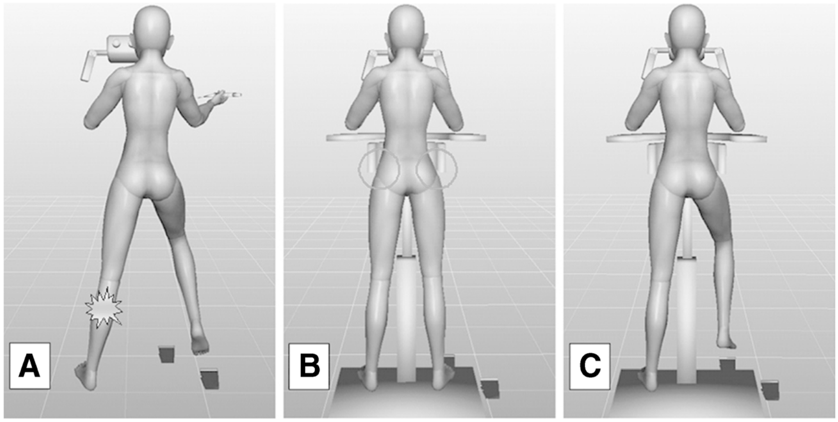


Fig. 1 Schematic drawings of a standing operation with and without the use of the Surgeon's Body Support Device. **a** During operations performed standing on one foot while using a foot switch, the body axis is unstable and the musculoskeletal load increases. Moreover, it is difficult for the surgeon to look down the operating microscope constantly. **b**, **c** The Surgeon's Body Support Device supports the surgeon's body at the iliac bone, which helps to stabilize the surgeon's body and reduce musculoskeletal loading on the axis foot and the right hand. Furthermore, the surgeon can continue to look down the operating microscope, even while using the foot switch

Materials and methods

During standing operations, operators often stand on one foot, which can lead to the instability of the body axis and greater musculoskeletal loading (Fig. 1a). We have developed a tool called the Surgeon's Body Support Device to support operators' bodies. Currently, there are few of these tools available for this purpose, and those that exist support surgeons' knees and iliac crests to reduce musculoskeletal loading on the right hand (Fig. 1b, c).

Surgical body supporter device and procedure

The Surgeon's Body Support Device is shown in Fig. 2. During a surgical procedure, it supports the knee and the iliac crest, thereby helping the surgeon to maintain a constant posture while standing. Consequently, the surgeon's body does not need to be supported by an arm while the foot switch is used, which means both arms are available for surgical manipulations.

In this study, 14 surgeons, with a mean±standard deviation age of 31.9±9.3 years, volunteered to emulate operations performed while standing, with and without the use of the Surgeon's Body Support Device. Each subject pressed foot switches, which were located 30 cm apart at each apex of a triangle, with his right foot. The subject continued this procedure at 1.5-s intervals for a total of 300 s. All subjects were instructed to ensure that their eyes remained in a position that enabled them to look down the operating microscope (Fig. 3).

Analysis of motion kinetics and musculoskeletal loading

During the simulation of the surgery, an MVP-RF8 three-axis wireless accelerometer (MicroStone Corporation, Nagano, Japan) and a KineAnalyzer (Kissei Comtec Co. Ltd, Nagano, Japan) analyzed the motion kinetics and musculoskeletal loading, respectively, in the presence and absence of the Surgeon's Body Support Device. A three-axis wireless accelerometer is often used to evaluate the pattern of motion defined as acceleration [1–4]. The three-axis wireless accelerometer was used to measure trunk acceleration along three axes (vertical, mediolateral, and anteroposterior). Jerk is a vector that represents the change in the acceleration of an object. A gradual change in acceleration signifies a very slight jerk. Thus, this vector represents the smoothness of motion. For mathematical purposes, the data from the

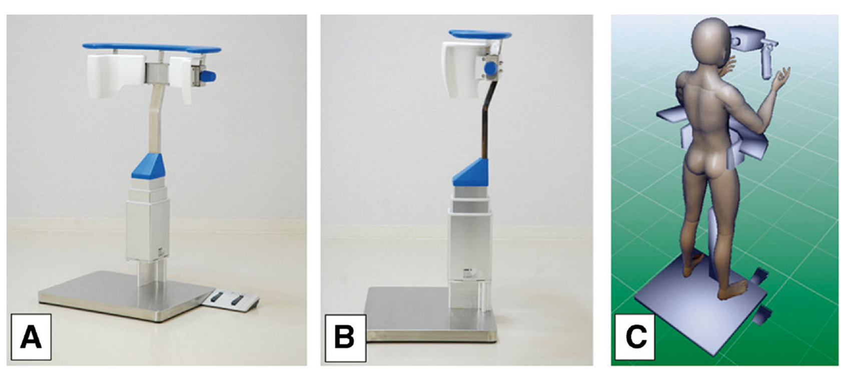


Fig. 2 The Surgeon's Body Support Device. **a**, **b** The height of the device can be adjusted to suit the surgeon's posture. **c**, The surgeon is supported

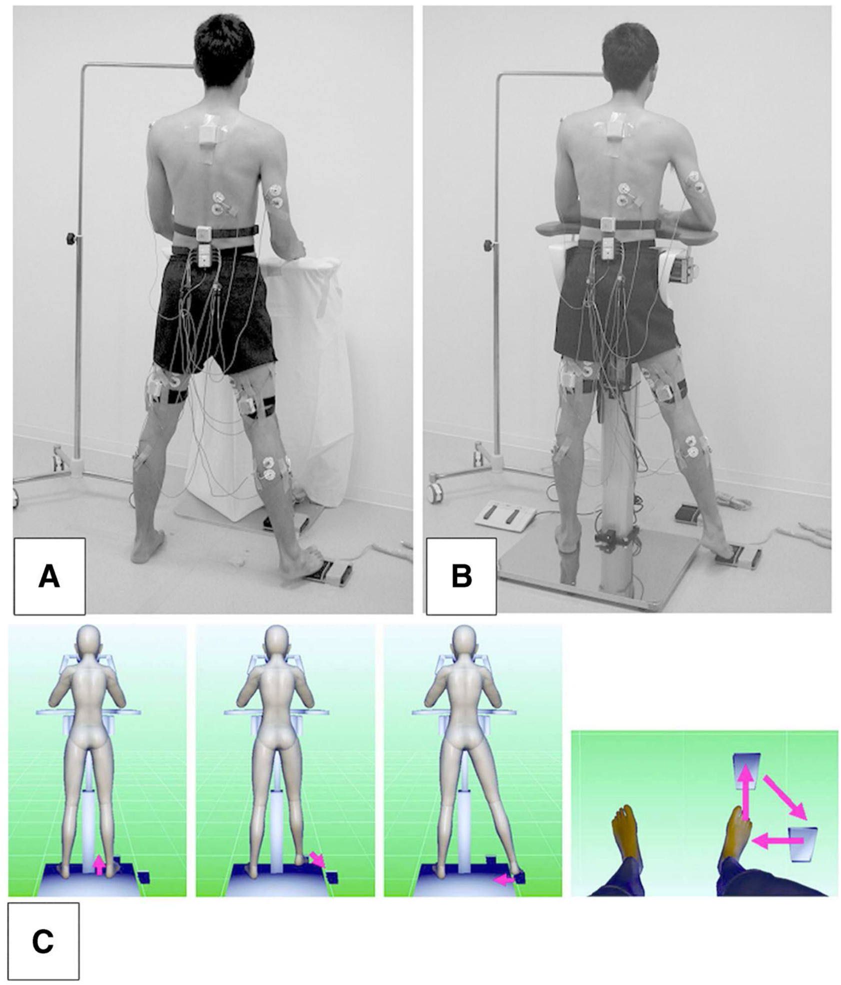


Fig. 3 **a** A subject's posture without the use of the Surgeon's Body Support Device and **b** a subject's posture using the Surgeon's Body Support Device, during the same surgical simulation. The three-axis wireless accelerometer and surface electromyography sensors were attached to the subject's body. **c** A schematic drawing of the test procedure. The subject pressed foot switches, which were located 30 cm apart at each apex of a triangle, with his right foot, and continued to do this at 1.5-s intervals for a total of 300 s

three-axis accelerometer sensors were converted to the root-mean-squares (RMS) [2]. The RMS is a measure of the dispersion of the data relative to zero. We focused on the stability of the body axis and the smoothness of the motion of the right foot; hence, sensors were placed on the neck and the right foot (Fig. 4a).

The KineAnalyzer is equipped with surface electromyography (SEMG) sensors, which determine the degree of

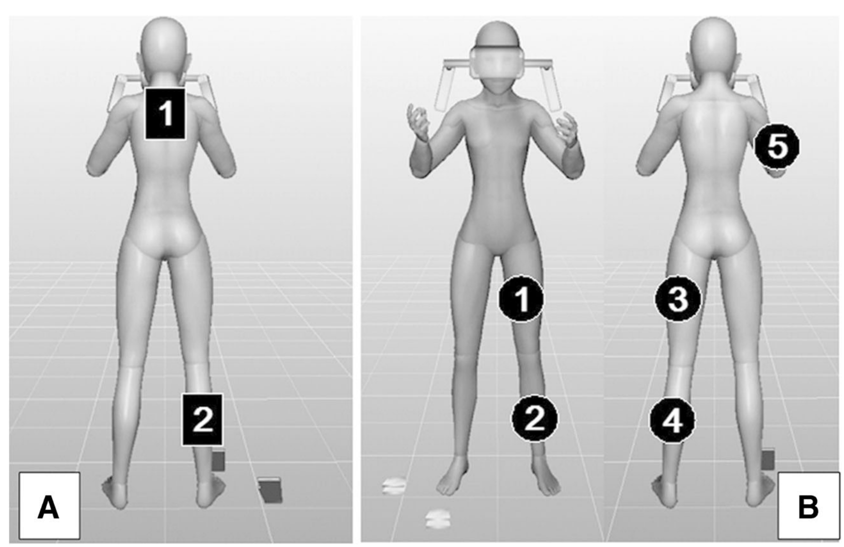


Fig. 4 **a** The three-axis wireless accelerometer sensors were placed on the neck to evaluate the stability of the body and on the right foot to evaluate the smoothness of the motion. **b** Surface electromyography sensors were placed on the left foot and right hand to assess musculoskeletal loading

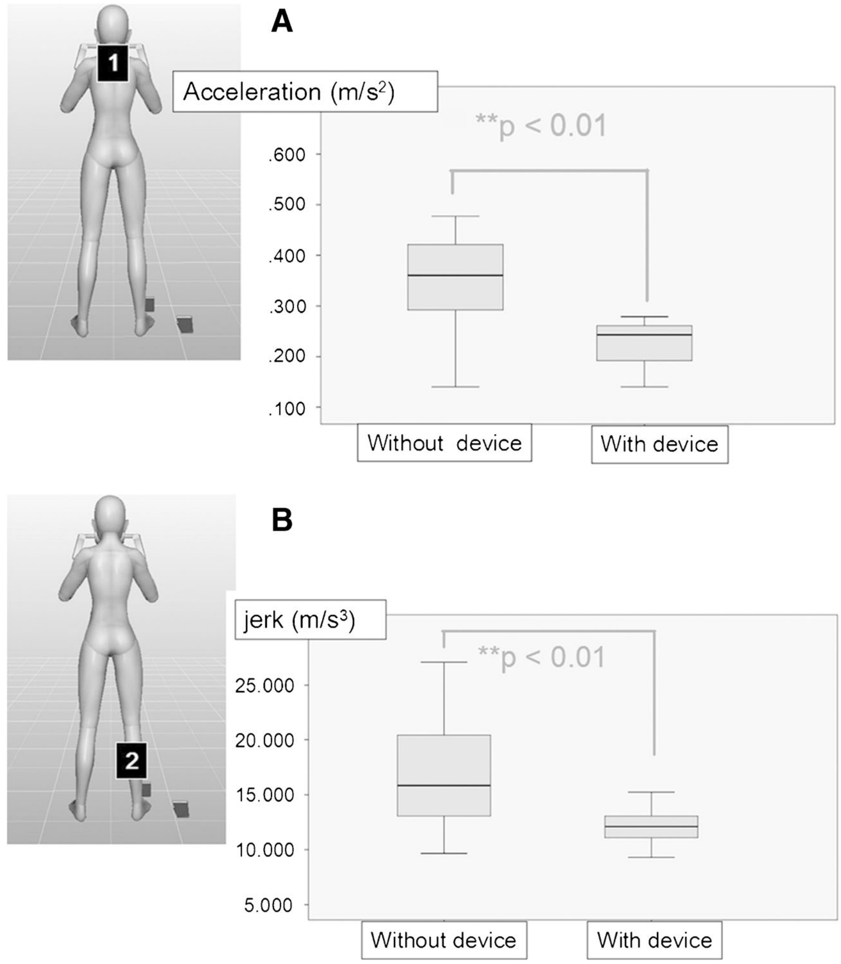


Fig. 5 **a** According to the data from the three-axis wireless accelerometer sensor placed on the neck, the axis of the subject's body was significantly more stable when the Surgeon's Body Support Device was used. **b** According to the data from the three-axis wireless accelerometer sensor placed on the right foot, the jerk of the right foot was significantly lower when the device was used

musculoskeletal loading. SEMG results are represented by a vector. The data from the SEMG sensors were converted to integrated SEMG values for mathematical purposes. We focused on musculoskeletal loading on the left foot and right hand, and sensors were placed on the appropriate parts (Fig. 4b).

Statistical analyses

The data were compared using the paired *t* test. All statistical calculations were performed using IBM® SPSS® software version 20 (IBM Corporation, Armonk, NY, USA). *P* values <.05 were considered statistically significant.

Results

Body stability and motion smoothness

The information gathered from the three-axis wireless accelerometer sensor placed on the neck indicated that the axis of the surgeon's body was significantly more stable when the

Table 1 Musculoskeletal loading on the left foot and right hand during simulations of surgery performed while standing, with and without the Surgeon's Body Support Device

	Left foot				Right hand
Surface electromyography sensor number	1	2	3	4	5
Musculoskeletal loading without support, mV/s	12.24±4.82	11.35±3.22	1.34±0.41	3.47±1.09	19.95±7.89
Musculoskeletal loading with support, mV/s	5.50±4.08	3.00±1.65	2.94±3.79	2.21±1.03	2.66±1.84
P value	<0.01	<0.01	NS	NS	<0.01

Data are presented as the means±standard deviations

NS not significant

Surgeon's Body Support Device was used. A significant difference was found in motion acceleration with and without the use of the device (0.23±0.04 vs. 0.36±0.13 m/s^2; P=.001) (Fig. 5a).

The information gathered from the three-axis wireless accelerometer sensor placed on the right foot indicated that using the device significantly reduced the jerk associated with the right foot compared with not using the device (41.61±13.14 vs. 55.22±17.93 m/s^3; P=.009) (Fig. 5b).

Musculoskeletal loading

When the supportive device was used, the musculoskeletal loading on the ventral side of the left foot was significantly reduced by 60–70 % compared with the musculoskeletal loading observed when the device was not used (5.50±4.08 vs. 12.24±4.82 mV/s; P=.001) (Table 1). Data from the SEMG sensor placed on the dorsal side of the foot indicated that there was no significant difference in the musculoskeletal loading when the device was used compared with when the device was not used (2.94±3.79 vs. 1.34±0.41 mV/s; P=.139). Data from the SEMG sensor placed on the right hand, which performs the surgical manipulations, indicated that simulated operations performed using the device generated approximately 10 % of the musculoskeletal load generated when the device was not used (2.66±1.84 vs. 19.95±7.89 mV/s; P=.001).

Simulation of surgery

Figure 6 presents the body stability, evenness of motion, and musculoskeletal loading data from a scenario simulating surgery while standing.

Discussion

Few studies have reported on the instability of a surgeon's posture and musculoskeletal loading during surgery performed while standing. In this study, we investigated these factors using a three-axis wireless accelerometer and SEMG sensors.

The three-axis wireless accelerometer analyzed the motion kinetics associated with operations performed while standing. If a surgeon's motion is uneven, the acceleration is greater. The smoothness of the motion was also evaluated in relation to jerk, which represents the change in acceleration of an object [5]. Mathematically, jerk is the rate of change of acceleration or the derivative of acceleration with respect to time. Recently, this method has been used frequently for motion analysis in the field of rehabilitation [1–4].

We utilized SEMG sensors to assess the musculoskeletal loading during surgery undertaken while standing. Previous studies have suggested that it is possible to evaluate muscle fiber activity from electromyograms [6, 7]. If considerable muscle strength is required, numerous muscle fibers must be activated. Accordingly, the electromyogram will have a high amplitude that represents the sum of the associated motor units. When muscle contractions are weak, the electromyogram will show low amplitudes.

Motion kinetics

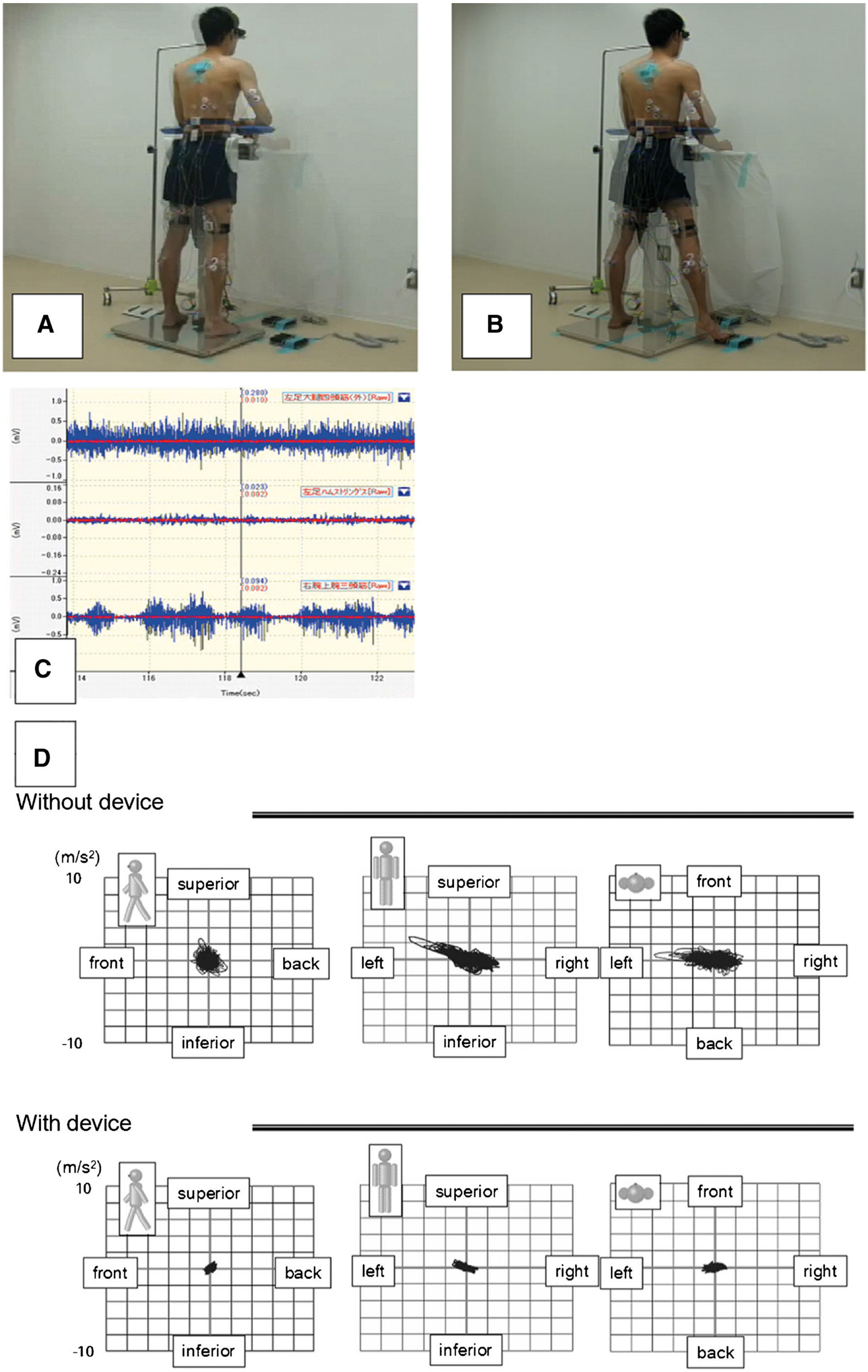
According to the data generated by the three-axis wireless accelerometer, conducting surgery while standing without the use of the Surgeon's Body Support Device led to unsteadiness and uneven body movements. When a surgeon stands on one foot, the device supports the body and contributes to the stability and smoothness of the surgeon's motion, including that of the right foot. The Surgeon's Body Support Device facilitates precise and fine surgical manipulations, which are vital in microsurgery.

Musculoskeletal loading

According to the data generated by the SEMG sensors, the use of the device led to less musculoskeletal loading on the left lower extremity and on the right hand, indicating that the surgeon could perform a long surgical procedure with lower musculoskeletal loads and steady hands. Specifically, this device reduced musculoskeletal loading on the ventral side of the lower extremity that was monitored. Moreover, procedures performed without this device resulted in high amplitudes within the electromyograms of the surgeons' right hands, suggesting that the right hand supported the entire body during a simulation, as shown in the scenario simulating surgery while standing. Therefore, the surgical manipulations performed by the upper extremity were unstable, especially when they were performed while the surgeon was standing on one foot. The use of the Surgeon's Body Support Device stabilized the lower part of the body by reducing musculoskeletal loading, leading to safe and stable surgical procedures. Thus, this device facilitates precise and comfortable microsurgery.

Conclusions

We investigated the usefulness of the Surgeon's Body Support Device during operations performed while standing, based on the results from a three-axis accelerometer and SEMG sensors. The device facilitated improvements in maneuverability and reduced musculoskeletal loading during procedures carried out while standing.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◀ **Fig. 6** **a**, **b** Superimposed photographs of a subject simulating surgery in the presence and absence of the Surgeon's Body Support Device. **a** The beginning of the task with no body instability in either situation. **b** Differences in the body's motion with and without the device. In the absence of the device, the instability of the subject's body was considerable. **c** Surface electromyographs showed low amplitudes during the procedure in the presence of the device, indicated by the *red lines in the upper and middle portions of the image*. When a surgeon's position changed to stand on one foot without the device, the electromyographs of the right hand showed periodic high amplitudes and, in this situation, it would have been difficult for the subject to perform precise surgical procedures with the right hand. **d** The three-axis wireless accelerometer sensors indicated high levels of motion acceleration without the use of the device

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Conflict of interest No financial xsupport was provided for this study. Takano Co., Ltd. played no part in the data analysis, interpretation, or in writing this manuscript. The authors have no personal or institutional conflicts of interest to declare.

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Comments

Yavor Enchev, Varna, Bulgaria

The manuscript of Ito et al. represents an intriguing paper as it addressed the problem of surgeon's stability and fatigue during neurosurgical procedures performed while standing. In order to find a solution for the problem, they developed a tool called the Surgeon's Body Support Device. The authors evaluated the efficacy of their device by analyzing neurosurgeons' kinematics and musculoskeletal loading during simulated procedures underwent while standing. The study included 14 volunteer surgeons, who were supplied with a three-axis accelerometer and surface electromyography sensors. The results with and without the use of the proposed device were compared. Based on their results, the authors concluded that the Surgeon's Body Support Device improves maneuverability and reduces musculoskeletal loading during simulated surgical procedures undertaken while standing. The study has an excellent design and it is perfectly performed. Finally, I hope that this device will be soon available and affordable for the neurosurgeons worldwide.

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Ihsan Solaroglu, Istanbul, Turkey

Neurosurgery is a stressful field. A neurosurgeon must have mental and physical stamina. However, the cumulative effect of chronic stress in our practice often results in burnout which has serious consequences such as poor job performance and decreased productivity. The physical workload, the numbers of call nights per week, and long working hours negatively affect the health of a neurosurgeon. In our daily practice, many of the procedures take hours to complete, and as stated by Ito et al., most of them are conducted while standing. Body axis instability and greater musculoskeletal loading during operations decrease maneuverability and also create a potential risk for musculoskeletal disorders for us. I believe every effort directed at the protection of the health and wellness of the neurosurgeon is worthwhile.

The Surgeon's Body Support Device, developed by Ito et al., is a candidate device, which may meet requirements and may be used in our daily practice. However, in this study, the data came from only simulated operations. I strongly recommend performing real procedures by using Surgeon's Body Support Device to explore whether this will provide better comfort for surgeons. Also, the effect of this device on patient outcomes should be evaluated in long term.