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ORIGINAL RESEARCH

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# Ergonomic advantage of pistol-grip endoscope in the ENT practice

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## Abstract

**Objectives:** Recent technology manufactured a nasopharyngeal videoscope with pistol-shaped grip (PG). This study aimed to assess the ergonomic feasibility of this novel device in daily ENT practice.

**Methods:** To assess the ergonomic impact of grip shape on ENT physicians, conventional grip videoscope (CG) and PG were utilized in this study. Surface electromyography (sEMG) was recorded to assess the muscle activity in the upper limb during endoscopy on a training model. Bilateral sEMG recordings were performed including thenar muscle, pronator teres muscle, brachioradialis muscle, and biceps brachii muscle. Mean value of the mean sEMG amplitude throughout the task in triplicated examinations (mMA) with each electrode, total values of four mMAs in both of the grip-side and the insertion tube-side limb muscles, and total value of all eight mMAs were calculated, and compared between CG and PG. Subgroup analyses were also performed in the experienced ENT physicians and the residents.

**Results:** PG provided significantly lower mMA values in thenar muscle and brachioradialis muscle of the grip-side limb compared with CG. Total value of four mMAs in PG was significantly lower compared with that in CG in the grip-side limb, and total value of all eight mMAs in PG was significantly lower compared with that in CG. Furthermore, total value of four mMAs in PG was significantly lower compared with that in CG in the grip-side limb, in both of the subgroups.

**Conclusion:** This is the first study to support the idea that the newly designed pistol-grip endoscope may have an ergonomic advantage over conventional endoscope for otolaryngologists in daily practice.

**Level of Evidence:** 4

KEYWORDS
electromyography, ENT practice, ergonomics, nasopharyngeal endoscopy

This work was performed at Kyorin University School of Medicine, Department of Otolaryngology-Head and Neck Surgery.

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## 1 | INTRODUCTION

Ergonomics is the scientific discipline based on the understanding of interactions among humans and other elements of a system. Ergonomics applies theory, principles, data, and methods to the design of equipment to optimize human well-being and overall system performance, especially to reduce the fatigue of operator. Ergonomic analyses are widely applied today to workplace and tool design in the industry,[1,2] military,[3] sports,[4] and medicine.[5] Recently, multiple studies reported ergonomic benefits in the field of medical endoscopy, for example, laparoscopy[6,7] and ureteroscopy.[8] These reports highlighted that it is important to understand the biomechanical stress on physicians during endoscopy to identify the factors that may contribute to fatigue and discomfort related to daily clinical practice. A flexible nasopharyngeal endoscopy (NPE) is a very common examination for otolaryngologists in daily clinical practice. Despite its common use, the ergonomic assessment concerning NPE has not been described yet. Flexible ENT endoscope is typically used on a patient in the sitting position through the nose by a physician in front of the patient's chair. However, a conventional ENT endoscope was developed to modify the gastrointestinal endoscope, which is mainly used on a patient in the left lateral decubitus position through the mouth by a physician in the patient's bedside. Thus, the shape of the conventional ENT endoscope could be upgraded based on the ergonomic point of view. Recent technology manufactured an ENT endoscope with pistol-shaped grip (PG), which could theoretically achieve less ergonomic stress enforced on physicians compared with conventional endoscopes (CG) during NPE (Figure 1). Furthermore, insertion tube of PG may be able to keep less bent, and more linear shape during examination compared with CG. Thus, PG may be able to further achieve reduced friction between the scope and nasopharyngeal mucosa to facilitate more smooth and efficient manipulation of the endoscope compared with CG. To assess the ergonomic feasibility of this novel device, this study was designed to investigate the biomechanical stresses on ENT physicians during NPE by measuring the surface electromyography (sEMG) on upper limb muscles of the physicians. Data obtained during CG and PG manipulations were compared with each other.

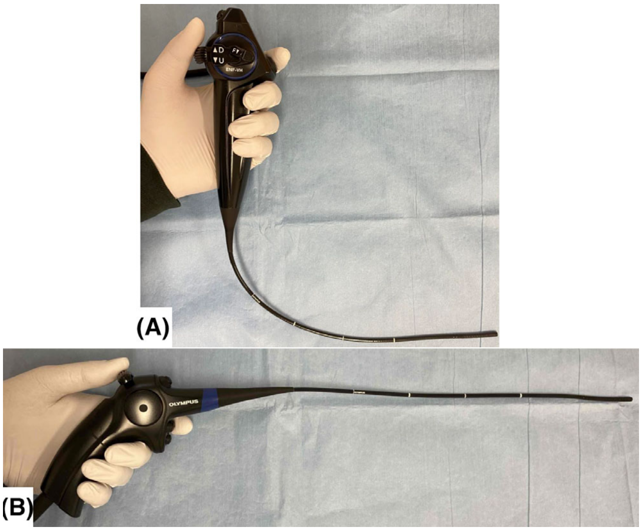


**FIGURE 1** Flexible ENT endoscopes incorporated in this study. Conventional grip videoscope (A, ENF-VH; OLYMPUS), and recently manufactured pistol-shaped grip videoscope (B, ENF-VH2; OLYMPUS) were used in this study

| | Electrodes |
|---|---|
| Grip-side | ① Thenar muscle (TM) |
| | ② Pronator teres muscle (PT) |
| | ③ Brachioradialis muscle (BR) |
| | ④ Biceps brachii muscle (BB) |
| Insertion tube-side | ⑤ Thenar muscle (TM) |
| | ⑥ Pronator teres muscle (PT) |
| | ⑦ Brachioradialis muscle (BR) |
| | ⑧ Biceps brachii muscle (BB) |

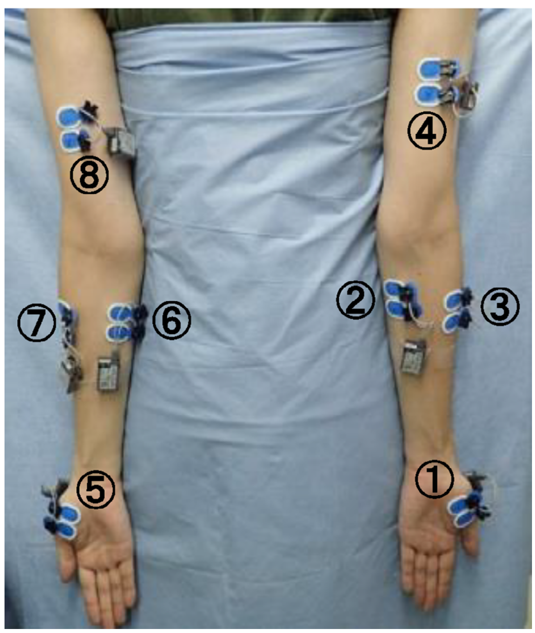


**FIGURE 2** Placements of surface EMG electrodes. Electrodes were placed on bilateral TM, PT, BR, and BB. Sixteen participants manipulated the grip in their left hands as shown in this figure, and residual two participants manipulated the grip in their right hands. BR, brachioradialis muscle; BB, biceps brachii muscle; TM, thenar muscle; PT, pronator teres muscle

## 2 | MATERIALS AND METHODS

### 2.1 | Subjects

ENT physicians and residents working at Kyorin University Hospital were recruited in this project, and written informed consent was obtained from all participants. This research complied with the tenets of the Declaration of Helsinki, and was approved by the institutional review board of Kyorin University School of Medicine (approval #779).

### 2.2 | Videoendoscopic equipment

Conventional grip videoscope (ENF-VH, CG; OLYMPUS, Tokyo, Japan) and newly developed pistol-grip videoscope (ENF-VH2, PG; OLYMPUS) were utilized combined with light source (OTV-S190, OLYMPUS), video processor (CLV-S190, OLYMPUS), and 2D monitor (OEV-262H, OLYMPUS) in this study. Based on the Olympus survey, the weight of the control section and the force required for the up/down angulation control lever operation in the newly designed PG were reduced approximately 30% and 20%, respectively, compared with those in CG. Concerning specifications in viewing angle, flexible angle, tip portion diameter, insertion portion diameter, and maximum insertion portion diameter, no differences were observed between these endoscopes. Instructions for the use of newly developed endoscope were explained to the physicians involved this study before they performed endoscopic manipulations.

### 2.3 | Surface EMG recording

A wireless sEMG system (TeleMyo Clinical DTS system; Noraxon, Scottsdale, AZ) was used to measure the muscle activity of physicians during endoscopy (Figure 2). sEMG detects the electric potential generated by muscle cells and creates an electromyogram that can be analyzed to determine the activation level of the target muscle. Utilized sEMG system allowed simultaneous recording of eight channels,

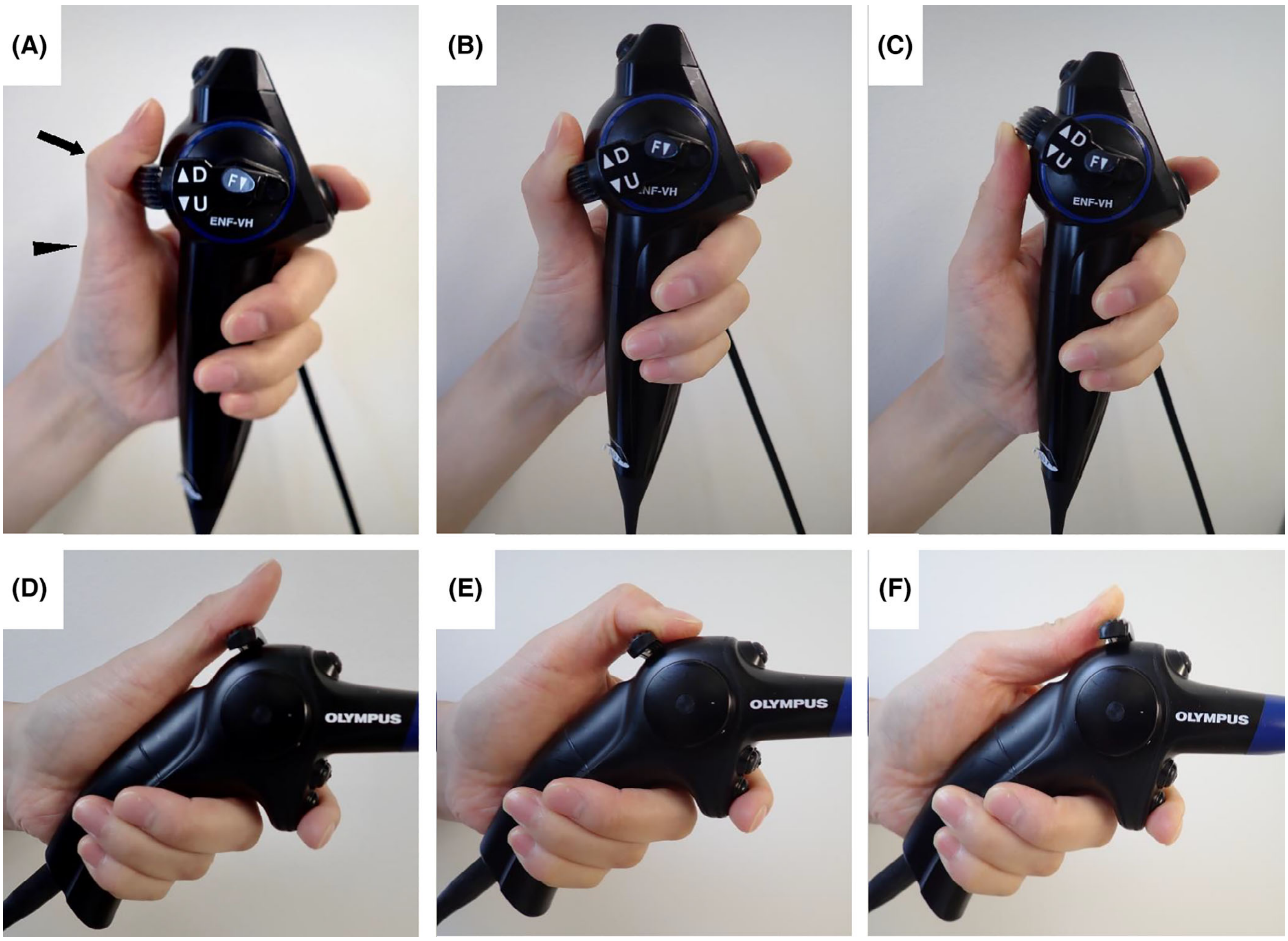


**FIGURE 3** Manipulation of the videoscope by the up/down angulation control lever. Images of the grip-side hand holding the CG (A–C) and PG (D–F) are shown. The control lever is regulated by thenar muscle (TM) to flex the metacarpophalangeal (MP) joint (arrow) and the caropometacarpal (CM) joint (arrowhead) of the thumb. Pictures at the neutral position (A, D), and at the up (B, E)/down (C, F) angulation control positions are shown. CG, conventional grip videoscope; PG, pistol-shaped grip videoscope

and sEMG electrodes (BlueSensor N; Ambu, Ballerup, Denmark) were placed on four upper limb muscle bellies in both of the grip-side limb and the insertion tube-side limb, as mentioned below. The sticking sites of the electrodes were cleaned with alcohol to reduce skin impedance, and each distance between electrodes was set at 22 mm. Computer software (MR3, version 3.7.27; Noraxon) was used for data analyses. The derived analog signals were sampled at 1.5 kHz, and digitized using a16-bit analogue to digital converter. Signals were filtered at a bandwidth of 10-500 Hz to eliminate noise recorded during the data collection process. Root mean square window of 50 ms was used for signal smoothing, and mean value of sEMG amplitude in triplicated examinations (mMA) was calculated on every muscle.[9,10]

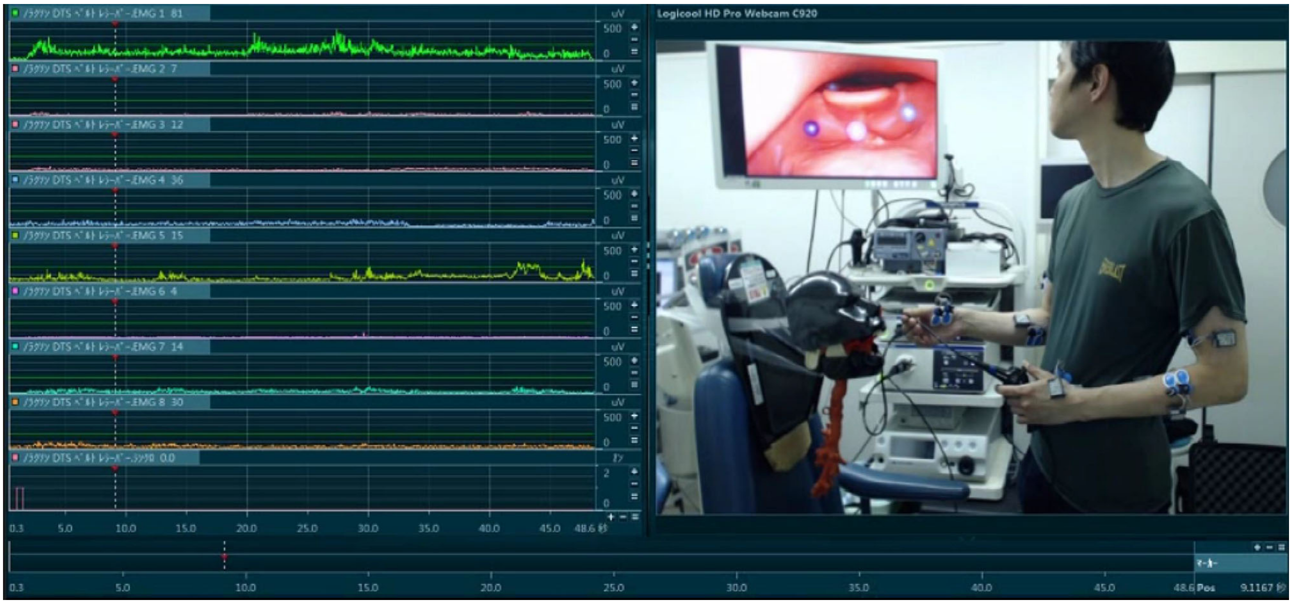


**FIGURE 4** Surface EMG recording during the NPE tasks. Simultaneous recording of sEMG in the targeted eight muscles of the participant was performed during NPE tasks performed on a training model set on a treatment chair. NPE, flexible nasopharyngeal endoscopy; sEMG, surface EMG

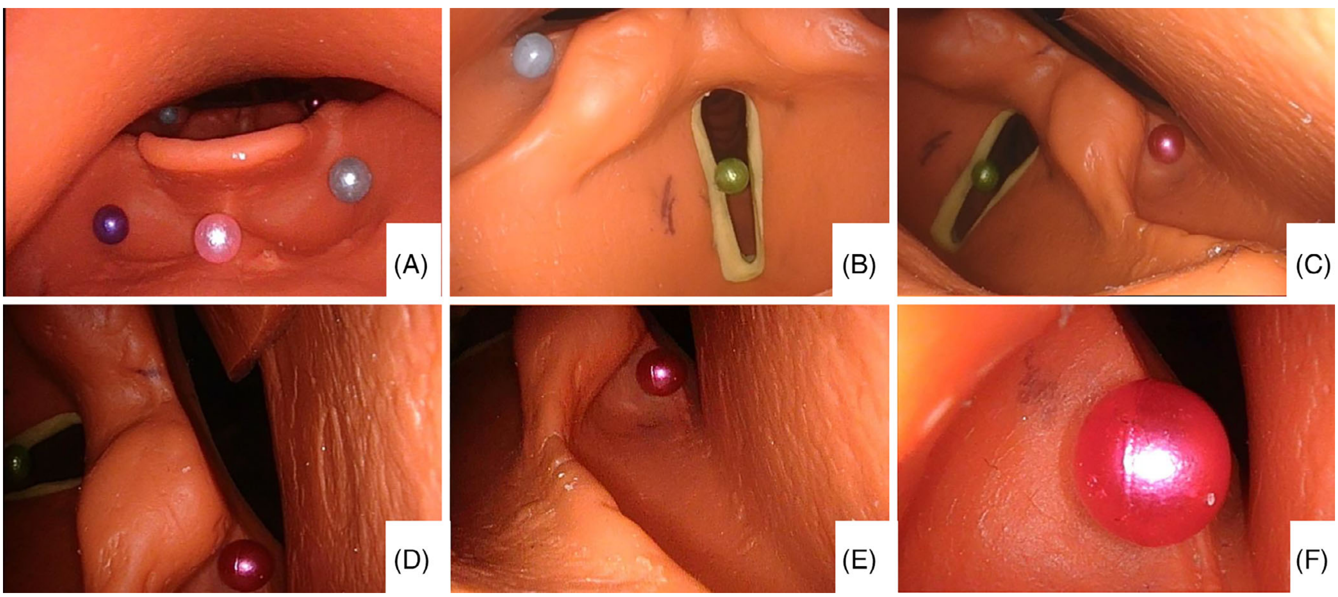


**FIGURE 5** A series of tasks utilized in this study. Endoscopic tasks consisted of the following 12 steps. (1) insert the tip through the nose; (2) hold the distant laryngeal view, A; (3) hold the close laryngeal view, B; (4) hold the left hypopharyngeal view, C; (5) manipulate the tip of the endoscope upward, D; (6) manipulate the tip of the endoscope downward, E; (7) touch the mark in the left pyriform fossa by the tip of the endoscope, F; (8-11) repeat steps 4-7 in the right hypopharynx; and (12) remove the endoscope. Each view was held for 5 seconds

## 2.4 | Electrode positions

During daily NPE using a videoscope, ENT physicians visualize the lesion in a 2D monitor. Thus, proper combination of vertical and horizontal visual adjustments in the monitor by manipulation of the endoscope is required for successful visualization of the target. In this process to achieve appropriate vision, vertical adjustment of the vision is mainly performed by manipulating the lever in the grip. The lever manipulation is regulated by thenar muscle (TM) to flex the metacarpophalangeal (MP) joint and the caropometacarpal (CM) joint of thumb[11] (Figure 3). On the other hand, horizontal adjustment of the vision is mainly performed by pronation and supination of the forearm in the grip-side. Representative muscles that pronate and supinate the forearm are pronator teres muscle (PT) and brachioradialis muscle (BR), respectively. The insertion tube-side of the endoscope is held and manipulated by multiple fingers including thumb, and thus, ipsilateral TM has an important role during NPE. Furthermore, bilateral biceps brachii muscle (BB) holds the endoscope during NPE. Thus, sEMG electrodes were placed on bilateral TM, PT, BR, and BB in this study (Figure 2).

## 2.5 | Tasks for endoscopic manipulation

A series of tasks to mimic daily ENT practice was performed on a training model (AIRSIM bronchi; TruCorp, Armagh, Ireland), set on a treatment chair in this study (Figure 4). Endoscopic tasks consisted of the following 12 steps (Figure 5). (1) insert the tip through the nose, (2) hold the distant laryngeal view for 5 seconds to mimic the dynamic assessment of the whole laryngo-pharyngeal region, (3) hold the close laryngeal view for 5 seconds to mimic the precise assessment of glottic region, (4) hold the left hypopharyngeal view for 5 seconds to mimic the assessment of left hypopharyngeal region, (5) manipulate the tip of the endoscope upward to mimic the assessment of left posterior pharyngeal wall and postcricoid area, (6) manipulate the tip of the endoscope downward to mimic the assessment of left aryepiglottic fold, (7) touch the mark in the left pyriform fossa by the tip of the endoscope to mimic biopsy or sensory test, (8-11) repeat steps 4-7 in the right hypopharynx, and (12) remove the endoscope. All the participants repeated the tasks three times on each endoscope alternately.

## 2.6 | Statistical analyses

The mean MA value of triplicated examinations (mMA) with each electrode was compared between CG and PG. Furthermore, the total values of four mMAs in the grip-side and the insertion tube-side limb muscles, as well as the total values of all eight muscles were calculated, and compared between CG and PG. Additionally, subgroup analyses were also performed in experienced ENT physicians and young residents for the further assessment of ergonomic stress during endoscopy. Wilcoxon signed-rank test was utilized for statistical

**TABLE 1** Individual values of mMAs in all participants and two subgroups

| | | mMAs (μV) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CG | | | PG | | | p values | | |
| | EMG No. | All participants N = 18 | Experienced ENT physicians N = 8 | Residents N = 10 | All participants N = 18 | Experienced ENT physicians N = 8 | Residents N = 10 | All participants N = 18 | Experienced ENT physicians N = 8 | Residents N = 10 |
| Grip-side | ① TM | 61.2 ± 28.9 | 62.1 ± 24.2 | 62.1 ± 24.2 | 42.3 ± 19.3 | 41.4 ± 17.5 | 41.4 ± 17.5 | <0.001 | 0.012 | 0.008 |
| | ② PT | 15.7 ± 7.5 | 14.4 ± 10.2 | 16.7 ± 5.4 | 15.3 ± 6.9 | 13.8 ± 5.6 | 16.5 ± 8.2 | 0.981 | 0.735 | 0.799 |
| | ③ BR | 28.0 ± 12.3 | 19.0 ± 6.7 | 27.8 ± 9.7 | 19.9 ± 7.2 | 28.3 ± 16.4 | 20.6 ± 8.2 | <0.001 | 0.036 | 0.007 |
| | ④ BB | 38.7 ± 12.3 | 30.1 ± 6.0 | 45.5 ± 12.6 | 35.1 ± 13.8 | 34.0 ± 18.0 | 35.9 ± 11.2 | 0.058 | 0.779 | 0.005 |
| Insertion tube-side | ⑤ TM | 89.1 ± 41.0 | 92.0 ± 34.2 | 86.8 ± 49.4 | 77.2 ± 34.8 | 87.5 ± 37.9 | 69.0 ± 33.7 | 0.136 | 0.779 | 0.110 |
| | ⑥ PT | 20.8 ± 28.3 | 27.6 ± 43.3 | 15.4 ± 8.4 | 13.8 ± 7.4 | 10.7 ± 5.1 | 16.1 ± 8.7 | 0.306 | 0.161 | 0.799 |
| | ⑦ BR | 20.3 ± 7.3 | 20.7 ± 6.9 | 20.0 ± 8.3 | 19.3 ± 8.0 | 18.8 ± 6.8 | 20.7 ± 6.9 | 0.223 | 0.208 | 0.646 |
| | ⑧ BB | 35.3 ± 18.9 | 25.7 ± 9.8 | 43.0 ± 22 | 36.9 ± 19.3 | 27.8 ± 13.3 | 44.2 ± 21.7 | 0.528 | 0.575 | 0.721 |

*Note:* Data are shown as mean values ± standard deviations.
Abbreviations: BB, biceps brachii muscle; BR, brachioradialis muscle; CG, conventional grip videoscope; mMA, mean value of surface EMG amplitude in triplicated examinations; PG, pistol-shaped grip videoscope; PT, pronator teres muscle; TM, thenar muscle.

**TABLE 2** Total values of mMAs in all participants and two subgroups

| | Total values of mMAs (μV) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | CG | | | PG | | | *p* values | | |
| | All participants N = 18 | Experienced ENT physicians N = 8 | Residents N = 10 | All participants N = 18 | Experienced ENT physicians N = 8 | Residents N = 10 | All participants N = 18 | Experienced ENT physicians N = 8 | Residents N = 10 |
| Four muscles in the grip-side | 143 ± 45 | 133 ± 57 | 152 ± 32 | 113 ± 29 | 110 ± 36 | 114 ± 25 | 0.001 | 0.036 | 0.005 |
| Four muscles in the insertion tube-side | 147 ± 57 | 166 ± 57 | 165 ± 60 | 166 ± 36 | 145 ± 32 | 149 ± 41 | 0.145 | 0.401 | 0.169 |
| All eight muscles | 309 ± 73 | 299 ± 70 | 317 ± 78 | 260 ± 47 | 255 ± 46 | 263 ± 50 | 0.006 | 0.263 | 0.007 |

*Note:* Data are shown as mean values ± standard deviations.
Abbreviation: mMA, mean value of surface EMG amplitude in triplicated examinations.

analyses. All analyses were performed using SPSS software version 26 (IBM, Chicago, IL), and statistical significance was set at $P < .05$.

## 3 | RESULTS

Fifteen ENT physicians (thirteen men and two women) and three junior residents (two men and one woman) participated in this project. ENT physicians consisted of eight experienced ENT physicians (board certified otolaryngologist; seven men and one woman) and seven senior residents in ENT program (six men and one woman). While all of the 15 ENT physicians had clinical experiences to use CG, none of the participants had experience to use PG before this study. Clinical experiences of 18 participants ranged 2 to 26 years, with the mean value of 8.3 ± 7.1 years. None of the participants had any neuromuscular pathology and impaired range of motion in the upper limb. Sixteen participants manipulated the grip in their left hands, and residual two participants manipulated the grip in their right hands. Furthermore, all participants used their thumb to manipulate the up/down angulation control lever in the grip-side. Data of eight experienced ENT physicians were compared with the data of ten residents for the subgroup analyses. PG provided significantly lower mMA values in two individual muscles of the grip-side limb compared with CG (TM, $P < 0.001$; BR, $P < 0.001$). However, no significant differences were observed between CG and PG in mMA values of the residual two muscles (PT, $P = 0.981$; BB, $P = 0.058$) in the grip-side. Furthermore, no significant differences were observed in all four muscles in the insertion tube-side when mMA values were compared between CG and PG (TM, $P = 0.136$; PT, $P = 0.306$; BR, $P = 0.223$; BB, $P = 0.528$) (Table 1). As for the total value of all eight mMAs, significantly lower value was observed in PG compared with that in CG ($P = 0.006$) (Table 1). Although the total value of 4 mMAs in PG was significantly lower compared with that in CG in the grip-side ($P = 0.001$), no significant difference was observed in the insertion tube-side between CG and PG ($P = 0.145$) (Table 2). As for the subgroup analyses, mMA values in PG were significantly lower compared with those in CG in the grip-side limb concerning two individual muscles in the experienced ENT physicians (TM, $P = 0.012$; BR, $P = 0.036$), and three individual muscles in the young residents (TM, $P = 0.008$ BR, $P = 0.007$; BB, $P = 0.005$). On the other hand, significant differences of mMA values were not observed between PG and CG in residual muscles of the grip-side limb in both of the experienced ENT physicians (PT, $P = 0.735$; BB, $P = 0.779$) and the residents (PT, $P = 0.799$). Furthermore, significant differences of mMA values were not observed between PG and CG in all four individual muscles of the insertion tube-side limb in both of the experienced ENT physicians (TM, $P = 0.779$; PT, $P = 0.161$; BR, $P = 0.208$; BB, $P = 0.575$) and the residents (TM, $P = 0.110$; PT, $P = 0.799$; BR, $P = 0.646$; BB, $P = 0.721$) (Table 1). Total values of four mMAs in PG were significantly lower compared with those in CG, in both of the experienced ENT physicians ($P = 0.036$) and the residents ($P = 0.005$) in the grip-side. However, no significant differences were observed between PG and CG in the total value of four mMAs in the insertion tube-side in both of the subgroups (experienced ENT physicians, $P = 0.401$; residents, $P = 0.169$). While no significant difference was observed concerning the total value of all eight mMAs between CG and PG in the experienced ENT physicians ($P = 0.263$), the value in PG was significantly lower compared with that in CG in the residents ($P = 0.007$) (Table 2).

## 4 | DISCUSSION

Recently, multiple benefits of ergonomics in the workplace have been highlighted in the literatures published in the field of otolaryngology. According to a survey by American Society of Pediatric Otolaryngology, more than half of the surveyed members experienced pain or discomfort that were attributed to their surgical practices. This report revealed that most of the pediatric otolaryngologists were interested in surgical ergonomics and were in need of more information on ergonomic principles.[12] Furthermore, based on a question survey, Little et al. showed that 77% of physicians who routinely perform endoscopic sinus surgery suffer physical discomfort or symptoms attributable to surgical procedures.[13] Recently, Smith et al. evaluated muscle activation and fatigue related to microlaryngeal surgery using sEMG.[14] They reported that surgery-related muscle fatigue and self-reported pain were reduced in favorable position compared with those in unfavorable position. They further concluded that favorable ergonomic position may help surgeons to avoid musculoskeletal injuries. As for the shape of the grip, recently launched multipurpose ENT shaver system (DIEGO ELITE Multidebrider, OLYMPUS) adopted angled handpiece for ergonomic handling of the instrument. It has been reported that this gun-grip shaver enabled the comfortable rotation of the cutting window by the finger(s) in the grip-side without twisting the wrist, even in the small-handed female ENT surgeons.[15] These articles demonstrate that poor workplace ergonomics could be a significant hazard during daily practice in the field of otolaryngology.[16]

## 4.1 | Analyses in all participants

To assess the ergonomic stress on ENT physicians during NPE, sEMG evaluations were performed in bilateral TM, PT, BR, and BB in this study. Representative muscle activities which contribute to pronation and supination of forearms were measured by mMA values in PT and BR, respectively. Furthermore, mMA value in TM was evaluated to represent the muscle activity to control the MP joint and the CM joint of thumb. Additionally, mMA value of BB was evaluated to assess the muscle activity to bend the elbow to hold the endoscope during NPE. Regarding the individual muscle activity in the grip-side, mMA value of BR in PG was significantly lower compared with that in CG. However, no significant difference was observed in the mMA value of PT between CG and PG. Although the difference between CG and PG was not statistically significant, mMA value of BB in PG represented lower numbers compared with those in CG in 14 of 18 participants (77%). As described below, further subgroup analysis revealed the significantly lower mMA value of BB in PG compared with that in CG in the grip-side limb of the residents. In addition, mMA value of TM in PG was significantly lower compared with that in CG. Concerning the individual muscle activity in the insertion tube-side, significant difference was observed in none of the four muscles. It has been reported that the efficiency to exhibit powerful pronation and supination of the forearm depends on the elbow joint angle, and the best elbow angles to exhibit the highest efficiency to pronate and supinate the forearm are 45° and 90°, respectively.[17] Due to the insufficient quality of recorded images, it was not possible to measure the elbow flexion angles of all participants in this study. However, the elbow flexion angle during NPE was measured following a previous study,[18] in the representative images of one participant (K.S.) (Figure 6). The measured angles in CG and PG were 126° and 88°, respectively. These numbers suggest that the elbow flexion angle during NPE in PG is relatively more efficient for supination of the grip compared with that in CG. In fact, in the grip-side, mMA value of BR in PG was significantly lower compared with that in CG. Thus, the lower activation level of BR required for supination during NPE in PG compared with that in CG may be partially responsible for the ergonomic advantage of newly developed PG over CG.

Additionally, 30% reduced weight of the control section may be partially responsible for the relatively smaller mMA value of BB in PG compared with that in CG. Furthermore, PG is mechanically designed to require 20% less power for the manipulation of the up/down

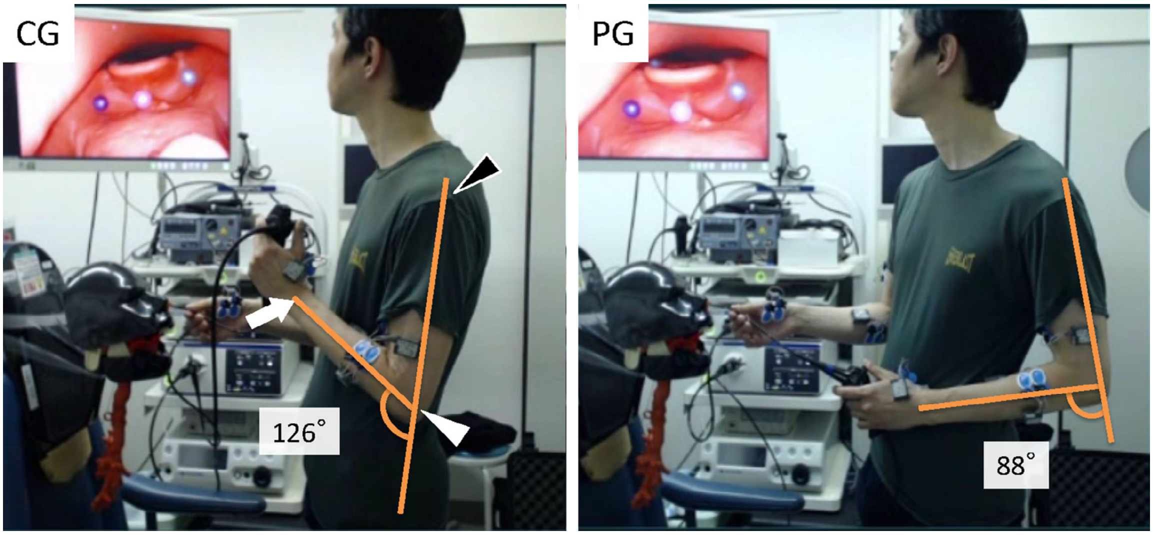


**FIGURE 6** The elbow flexion angle during NPE. Three landmarks were set on the still images of one participant during NPE at the task to hold the distal laryngeal view. The landmarks were (a) the acromion (black arrowhead), (b) the humerus lateral epicondyle (white arrowhead), and (c) the middle point between the radial styloid process and the ulnar head (arrow).[18] Lines to connect a-b, and b-c were drawn, and the angles between these lines were measured to assess the elbow flexion angle in CG and that in PG. CG, conventional grip videoscope; NPE, flexible nasopharyngeal endoscopy; PG, pistol-shaped grip videoscope

angulation lever compared with CG. Not only the pistol-shape of the grip, but also this mechanical design would be responsible for the significantly smaller mMA value of TM in PG in the grip-side compared with that in CG. The total value of four mMAs in the grip-side muscles and that in the insertion tube-side muscles, as well as the total value of all eight mMAs were evaluated for the comprehensive assessment of ergonomic feature in the newly developed PG. Our study revealed that, the total value of four mMAs in the grip-side, and the total value of all eight mMAs in PG were significantly lower compared with those in CG. These results suggested that the newly-designed PG may have ergonomic advantage over CG due to lower ergonomic stress required for supination of the grip, less power required to hold the endoscope, and reduced force requested to manipulate the control lever.

In this study, all participants used their thumb to manipulate the up/down angulation control lever in the grip-side. However, some ENT physicians may manipulate the lever using the index finger with the scope upside down. Thus, it would be beneficial to assess the ergonomic feasibility of PG on the ENT physicians who manipulate the lever using the index finger, in the future.

### 4.2 | Subgroup analyses

In both of the subgroups, mMA values of TM and BR in PG were significantly lower compared with those in CG in the grip-side. Furthermore, in the residents, mMA value of BB was also significantly lower compared with that in CG in the grip-side. Although CG is rather heavier than PG, mMA value of BB in the grip-side was statistically similar when CG and PG were compared with each other in the experienced ENT physicians. The experienced ENT physicians may have been already gotten used to hold CG through multiple opportunities to manipulate this familiar endoscope through daily practices. As for the total values of mMAs, in both of the subgroups, total value of four mMAs in PG was significantly lower compared with that in CG in the grip-side. Furthermore, in the residents, total value of all eight mMAs in PG was also significantly lower compared with that in CG. These results suggest that PG may have ergonomic advantages on both of the experienced ENT physicians and the residents. However, this newly developed equipment may represent superior ergonomic benefits on the residents over the experienced ENT physicians to perform NPE.

### 4.3 | Limitations of this study

Most of the participants were experienced with CG through daily ENT practice, and they may have preferred CG. Thus, this study could have underestimated the advantages of PG over CG. Furthermore, gender effect was not able to be assessed due to small number of female participants. Additionally, the weight of PG is 90 g less than that of CG. Therefore, ergonomic advantage of PG over CG may be attributed to not only the difference in the shape of the grip, but also the difference in the weight of the endoscope. Especially, ergonomic advantage of PG observed in BB may be affected by this weight difference, because this muscle is used to bend the elbow to hold the endoscope during NPE. Surface EMG is a non- invasive technique to measure muscle activity as electrical signals during muscle contraction and relaxation cycles.[9,10] Mean value of sEMG amplitude during the specific task has been used to measure the muscle electrical activity in a patient with dystonic gait.[10] Furthermore, integrated sEMG value was used as an index of total muscle work to assess the ergonomic influence of handle design on surgeons.[19] To follow these studies, mMA value was used as an objective parameter to evaluate the ergonomic impact of grip design on targeted muscle during NPE, in this study. However, the sEMG value at the maximum voluntary contraction is often recorded as a reference value of a targeted muscle, to utilize the normalized sEMG value as a parameter to evaluate the level of muscle fatigue.[6-8,14] Furthermore, a self-reported questionnaire has been also used as a subjective parameter to evaluate ergonomic environment surrounding surgeons.[13,14] A self-reported questionnaire may interpret the clinical benefit of the ergonomic advantage of PG reported in this study. Thus, future studies should involve more number of proper participants for further subgroup analyses. Furthermore, it would be beneficial to design a study to evaluate the ergonomic load for ENT physicians during NPE related to the weight of the endoscope. Additionally, future studies should evaluate the normalized sEMG value and a self-reported question survey as an objective and subjective parameter, respectively, to assess the ergonomic validity of PG on ENT physicians during NPE.

## 5 | CONCLUSION

This is the first report to suggest the ergonomic feasibility of the pistol-designed grip featured in the novel ENT endoscope. Our study using sEMG suggested that PG may have ergonomic advantage over CG due to (1) lower ergonomic stress required for supination of the grip, (2) less power required to hold the endoscope, and (3) reduced force requested to manipulate the control lever. Furthermore, subgroup analyses suggested that PG may have ergonomic advantages on both of the experienced ENT physicians and the residents to perform NPE. Although each routine office NPE may require limited effort for experienced ENT physicians, future studies to involve more number of participants, and to assess objective and subjective parameters could make a contribution to the improvement of ergonomic environments surrounding the otolaryngologists.

**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

**AUTHOR CONTRIBUTIONS**

Itaru Watanabe and Koichiro Saito contributed to conception and design of this study. Itaru Watanabe, Makoto Miyamoto, and Koichiro Saito contributed to acquisition of data. Itaru Watanabe and Makoto Miyamoto contributed to data analysis. All authors contributed to interpretation of data. Itaru Watanabe and Koichiro Saito drafted the manuscript, and Hideki Nakagawa and Koichiro Saito revised the manuscript critically for important intellectual content. All authors approved the final version of manuscript for submission.

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