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Face-guard to prevent droplet transmission of diseases during kendo practice: Efficacy, comfort, and heat stress

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Abstract

Faced with the 2009 influenza pandemic which caused widespread disruption to university and athletic activities, we took novel measures to prevent the H1N1 virus from decommissioning our university's kendo team. The 22 members of the team were asked to follow a preventive regimen including hand-washing, gargling, and wearing a specially-created facemask-like mouth guard during kendo practices. We monitored their body temperature and health. We suspected that the mouth guard may interfere with proper ventilation and cause heat stress. To evaluate the its practicality, we tracked WBGT and participants' ratios of sweat to body mass, and gave an opinion survey covering 20 practices following introduction of the mouth guard. During this time, two participants missed one practice each because of heightened body temperature, and there were no other incidents of suspected illness including influenza. Compared with the practice before introduction of the mouth guard, participant' ratios of sweat to body mass increased during the first practice using the mouth guard. However, examination of multiple practices before and after introduction of the mouth guard revealed no significant increase in sweat ratios. In fact, as WBGT decreased towards the end of the experiment, ratios of sweat to body mass decreased significantly. We therefore conclude that heat stress induced by the mouth guard was minimal. Furthermore, while there was no control group for direct comparison, we believe our regimen of preventive measures was effective. We recommend other kendo clubs to introduce similar procedures including use of a mouth guard during influenza season.

I. Introduction

Influenza struck an unusual level of fear across the world in 2009. In the face of pandemic, the authors took novel measures to prevent the H1N1 virus from decommissioning their university's kendo team.

Influenza is spread by droplets when infected persons cough or by direct contact[21.] Transmission, as judged by viral shedding, usually peaks during the first 1-3 days of symptoms, but can occur 1-2 days before symptom onset and continue for up to two weeks after symptom onset[2]. Symptoms include, "high fever, cough (usually dry), headache, muscle and joint pain, severe malaise (feeling unwell), sore throat, and runny nose," as stated by the World Health Organization (WHO)[21]. Although highly contagious, influenza can be best prevented by vaccine, and also by hand-washing and covering the mouth and nose when coughing. Influenza cases usually peak during winter, and people of all age groups are susceptible, although children and older adults are at heightened risk of complications[21]. According to the Japanese Ministry of Health, Labour and Welfare, as of March of 2010, 1 out of every 6 Japanese citizens had at some point in their life been diagnosed with influenza[16].

In March of 2009, the discovery of a new strain of influenza—influenza A (H1N1) pdm, popularly known as H1N1 or swine flu—spreading between people signaled the beginning of a global pandemic[5], categorized as Phase 6, the highest phase on the WHO's alert scale[22]. The pandemic was marked by fear and uncertainty[5]. Hospitalizations and complications from H1N1 were unusually common for children and teenagers[8,10,20]. In Japan, transmission among minors was shown to be sustainable[17], and about 18,000 schools canceled individual classes including several hundred which closed temporarily due to H1N1 fears[9]. From the end of July, 2009 to the end of March, 2010, an estimated 21 million cases of suspected flu were reported in Japan[10], including 675 cases in the university of the present study (student population around 7,500) during the 2009-2010 winter flu season[6]. The vast majority of these cases were probably caused by the H1N1 strain[9].

Kendo is a traditional martial art practiced similarly to a sport in clubs and schools throughout Japan. While there are no studies directly linking kendo and influenza infection, there were several reasons for considerable concern for participants in university kendo. First, participation in sports has been linked with elevated influenza transmission in young people[7,15]. Second, participants in kendo often find themselves face-to-face with their opponent, screaming at distances of about 40cm (This is an infighting position known as *tsuba-zeriai*.) and providing an optimum transmission scenario for influenza. Third, although kendo is an indoor sport, due largely to a tradition of self-discipline, participants often practice to the point of exhaustion in extreme heat or cold. Again, while there are no studies linking kendo with weakened immune conditions, participants may feel pressured to continue to practice despite the appearance of flu-like symptoms. Furthermore, in the 2009 West Japan College Tournament in Fukuoka on May 23-24, 48 out of 116 men's teams and 51 out of 112 women's teams were forced to withdraw due to concern over influenza outbreaks at their institutes[12,13].

Therefore, in cooperation with the Gifu University Kendo Team, the authors decided to institute preventive measures to ensure the vitality of the team during the peak of the

H1N1 pandemic. These measures included increased hand-washing and gargling－which has been shown to be effective for preventing upper respiratory tract infections[19]－monitoring club member health and body temperature and enforcing absence during suspected illnesses, and, finally, compulsory wearing of a "mouth guard." The mouth guard was designed to prevent common viral transmissions, in analogy to a typical eye guard which may prevent rare but serious injuries. It was invented to act in lieu of a typical cold－prevention or surgical mask, which either blocks or redirects expelled aerosols[19]. We were particularly concerned with the feasibility of wearing such a guard during daily kendo practices, especially because a mouth guard inherently restricts airflow around the participant's face, and restrictions to airflow and sweat evaporation are well-known factors contributing to heat stress[3,4].

This study looks at the efficacy of the adopted hygienic measures and focuses on the introduction of the mouth guard. We monitored the health of kendo participants and stress －including discomfort and heat stress as indicated by sweat ratios－induced by the mouth guard. We concluded that, although uncomfortable at first, participants became accustomed the mouth guard, and－by means of the mouth guard, hygienic measures, or sheer luck－participants in our kendo club avoided influenza and remained relatively healthy during the study period.

II. Methods

1. Development of the mouth guard

The main purpose of the mouth guard was to block droplets expelled in the breath of kendo participants, particularly when they are in close proximity to an opponent, such as in the *tsuba-zeriai* position. The guard had to meet several additional requirements as well. It had to be worn securely as an addition to the standard uniform and pose no safety threats. It had to be transparent so as not to obstruct vision, and comfortable enough so as not to impede the concentration of the wearer.

In cooperation with the kendo equipment manufacturer, Budo Suzuki (Osaka, Japan) we developed the final version of the mouth guard to fit inside the kendo mask (*men*) over the mouth It was made of flexible, 2 mm-thick gray-tinted or clear acrylic as pictured in Figure 1. Participants were able to remove it quickly for washing and then reinsert it before practice.

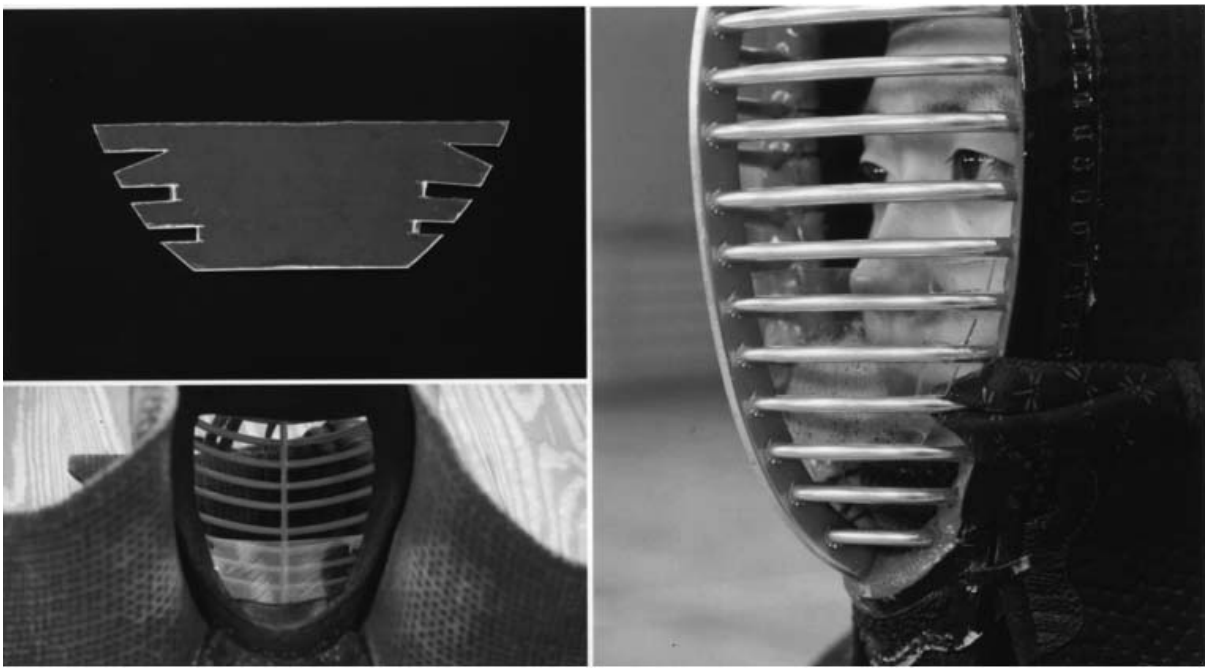

Figure 1: Design of the mouth guard for use in kendo. The mouth guard was designed to fit inside the kendo mask during practices and prevent droplet transmission of viruses such as influenza. It was made of clear, flexible acrylic. ***Image reproduced from Kendo Nippon, Vol. 420, 2011, p. 120.***

2. Subjects

All members of the Gifu University Men's and Women's Kendo Teams participated in this study, including 14 men and 8 women (n=22), 19-22 years old (mean=20.4 years). Although all team members were required to use the mouth guard and follow specified measures for influenza prevention, participants gave their voluntary and informed consent to participating in the study.

3. Design and Protocol

Because of perceived risks of influenza infection and the benefits of preventive measure, all participants followed a single set of guidelines and were treated the same throughout the study. There were no alternative or control groups. In this study we report on team practices from September 18 until October 23, 2009.

All participants were required to adopt the following preventive measures:

A. Hand washing

Participants were required to wash their hands with detergent and water before and after team practices, and before drinking water during breaks in team practices. After washing their hands, they were required to spray them with WellPass, (0.2% antiseptic solution containing ethanol (Maruishi Pharmaceuticals, Osaka, Japan). This preventive measure was introduced on August 25, and continued for the duration of the study.

B. Gargling

Participants were required to gargle after hand-washing before and after team practices, and before drinking water during breaks in team practices. This preventive measure was also introduced on August 25 and continued for the duration of the study.

C. Mouth Guard:

All participants were required to wear the mouth guard to every team practice beginning on September 29.

D. Reporting body temperature and abstaining from practices

Beginning on October 1, participants recorded their underarm temperature every morning after waking up and before each practice. If this temperature was 37.2℃ or higher participants were required to refrain from practicing. We based this threshold on reports such as the CDC H1N1 guideline to remain home until 24 hours after oral temperature has fallen below 37.8℃[6].

We monitored the following items:

A. Wet bulb globe temperature (WBGT):

During each practice, WBGT was recorded at 5 minute intervals by an electronic recorder (WBGT-101, Kyoto Electronics, Kyoto, Japan) placed in the interior of the practice hall away from any doors or windows. The WBGT for a given practice was taken as the mean of these recordings.

B. Body weight, water intake, and ratio of sweat to body mass

Participants recorded their body weight before and after each team practice as well as the amount of fluids (water or diluted sports drink) ingested during team practices. Amount of sweat was calculated as the amount of body weight lost minus the amount of water ingested during a given practice as follows:

Amount of sweat [kg] = (pre-practice body mass [kg] + water intake [kg])－post-practice body mass [kg]

Then the ratio of sweat to body mass (hereafter referred to as sweat ratio) was calculated as,

Ratio of sweat to body mass [%] = (amount of weat [kg] / pre-practice body mass [kg]) ×100.

These were recorded both before and after introduction of the mouth guard and other preventive measures.

C. Underarm temperature

As stated above, beginning on October 1st, participants recorded their underarm temperature every morning after waking up and before each practice.

D. Attendance

Participation in team practices was mandatory except in cases of schedule conflict with classes or underarm temperature of 37.2℃ or higher.

E. Discomfort survey

On the October 1, 10, and 23, participants were asked to describe their level of discomfort associated with the mouth guard (worn beginning on September 29). They chose from three levels of discomfort; *taihen iki-gurusii* [extreme discomfort (awfully stuffy/suffocating)], *sukoshi iki-gurushii* [moderate discomfort (a little stuffy/suffocating)], or *ki ni naranai* [no discomfort/ I don't mind it.].

The study was concluded on October 23, twenty practices after introduction of the mouth guard.

4. Statistics

The Wilcoxon signed-rank test was used to compare average sweat ratios in the five practices (September 18-26) leading up to the mouth guard with the five practices (September 29 - October 6) immediately following introduction of the guard and the last five practices (October 17-23) of the study. The Wilcoxon signed-rank test was also used to compare changes between the practice before and the first practice with the mouth guard. We set the level of significance at $p<0.05$.

Ⅲ. Results

All participants completed the study; however, due to schedule conflicts, not all of the participants were present on the dates included in statistical analysis, as noted in parentheses (n = number of participants with data). From September 29, when the mouth guard was introduced, participants missed a mean of 23% of practices due to schedule conflicts. For technical reasons, WBGT and sweat ratio data was not collected on September 22 and October 1.

The primary concern of this study was prevention of influenza-like illnesses detrimental to team practices. Therefore, underarm temperature was recorded as a measure of health. From October 1 until the conclusion of the experiment a total of two male participants reported abnormal underarm temperature on one day each. (October 8, pre-practice temperature = 37.4℃, and October 16, pre-practice temperature = 37.2℃) Accordingly, each of these participants refrained from practice on that day, but resumed practice the next day, once the fever had subsided. From October 1, this represents 0.36% of member-practices excluding those missed due to schedule conflicts. Because both of these participants recovered in one day, we deduce that fever was not due to influenza. No other participants recorded abnormal underarm temperatures, and we conclude that none of the participants contracted influenza.

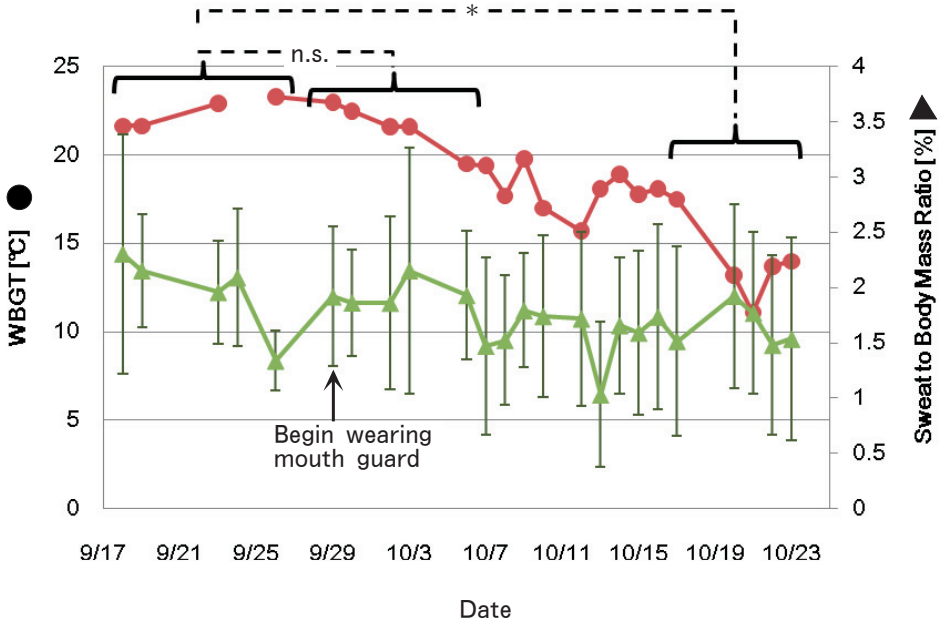

Figure 2. Change in WBGT and mean sweat to body mass ratio. Participants began wearing the mouth guard on September 29. When compared to the five days before introduction of the mouth guard, there was no significant change in sweat ratio (n.s., p=0.057) in the five days beginning when the mouth guard was introduced. However, the WBGT decreased over the course of the study, and there was a significant decrease (* p=0.006) in sweat ratio of the final five days in the study.

Also of importance was the wearability of the mouth guard, i.e. whether or not the mouth guard had a negative impact on practice quality. We were concerned that the mouth guard might interfere with ventilation and thereby contribute to heat stress. Changes in WBGT and participants' amounts of sweat were therefore monitored during practices. As shown in Figure 2, WBGT tended to decrease smoothly with only three sharp increases of greater than 2℃ from the previous day (October 9, 13, and 21). Based on a previous study from our laboratory[16], in general, we therefore expected sweat ratios to decline accordingly, and any major variations in sweat ratio could be due either to temperature fluctuations on these three days or controlled changes such as introduction of the mouth guard or variations in practice content.

Sweat ratio calculated for the practice before (September 26) and the first practice (September 29) with the mouth guard was introduced revealed a significant increase (n=10, p=0.009) as show in Figure 2. However, the sweat ratio on had fluctuated to a particularly low level on September 26. A comparison of averages from five practices immediately before to five practices immediately following introduction of the mouth guard showed no significant change (n=19, p=0.057), and a comparison of five practices immediately before introduction of the mouth guard to the last five practices of the study reveal a significant decrease in sweat ratio (n=19, p=0.006). Indeed, a decrease was expected because of the lower WBGT near the end of the study.

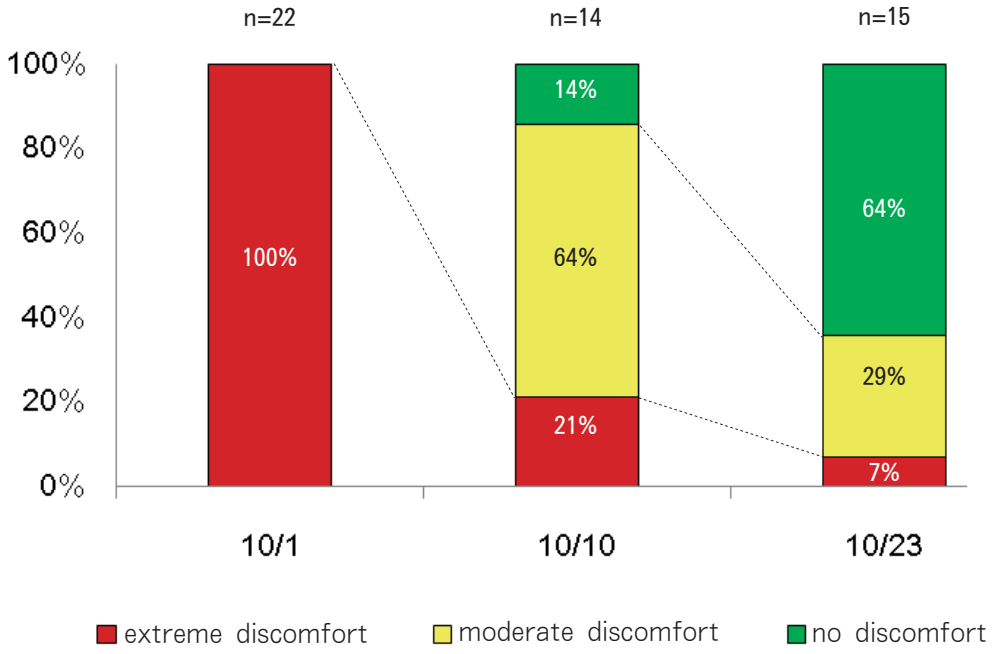

Figure 3: Participants' reported comfort of the mouth guard. The mouth guard was first worn on September 29, and the survey was conducted three times after practices thereafter. Although 100% of participants felt extreme discomfort shortly after introduction of the mouth guard, by October 23, by the end of the study, the majority of participants were not bothered by the mouth guard. On October 1, 22 participants reported to practice and participated in the survey, on October 10, 14 participants were present, and on Ocotber 23, 15 participants were present.

Also, we were concerned about participants' perceived discomfort with the mouth guard, and participants were therefore asked to report discomfort associated with the stuffiness of the mouth guard on October 1, 10, and 23. As shown in Figure 3, all participants felt extreme discomfort on October 1. The mouth guard was stuffy and unfavorable. However, discomfort mitigated so that one week later the majority of participants reported only moderate discomfort, and by the end of the study the majority reported that they felt no discomfort associated with the mouth guard.

Ⅳ. **Discussion**

Although there are no groups for direct comparison, we believe the result of only two participants missing one practice each due to fever speaks well of our preventive measures. These illnesses were minor, isolated cases that did not spread to other participants. Furthermore, the study took place as diagnosed cases of H1N1 were beginning to skyrocket in Japan[9,16]. During the last three weeks of the study, 45 cases of influenza were reported within university[6], so we know the possibility of contracting influenza in addition to colds and other illnesses existed, and we conjecture that introduction of preventive measures during practice heightened participants' precaution outside of practices as well.

We cannot say with whether or not our introduction of hand-washing, gargling, and mouth guards decreased participants' chances of contracting influenza or other illnesses. However, a previous study has shown that using a face mask in conjunction with hand-

washing lowers rate of illnesses in university students living in dormitories, although use of a face mask alone, or hand-washing alone[1(ア)①1] did not yield conclusive benefits. We therefore suggest that the mouth guard should be considered as one part of a comprehensive preventative regimen that includes increased hand-washing at the very least.

Along with the potential benefits of the mouth guard, however, the disadvantages such as induced heat stress should also be considered. In our study, we judged heat stress by changes in ratios of sweat to body mass, and were particularly concerned by the increase in sweat ratio from the practice before introduction of the mouth guard (September 26) to the first practice with the mouth guard (September 29). Since the change in WBGT was less than half a degree across these two days, the difference in sweat ratio may have been due to the mouth guard's restricted ventilation. This is supported by the students' unanimously reported discomfort on October 1. However, the sweat ratio on September 26 was lower than any previous day in our study, and we expect some variation in sweat ratio due to differences in practice contents, for example. Since a comparison of five practices immediately before and five practices immediately after introduction of the mouth guard revealed no significant difference, we believe that the mouth guard caused minor if any increase in heat stress and sweat ratios. Also, as athletes acclimate their bodies to changes in WBGT over several days[16], the participants in our study may have acclimated themselves to the mouth guard. By the end of the study, the decline in WBGT was reflected in a decline in sweat ratio compared to the levels before introduction of the mouth guard. Furthermore, although all participants expressed extreme discomfort shortly after introduction of the mouth guard, the majority became used to the mouth guard and reported that they no longer minded it by the end of the study.

Nevertheless, we do not recommend the mouth guard as a permanent fixture inside the *men*. Rather, we feel it should be introduced in December, or at the beginning of flu season. During this period, temperatures are usually falling and athletes are not in danger of heat stress. Once flu season has ended, use of the mouth guard may be discontinued. We particularly recommend the mouth guard for use in schools, since the 2009-2010 H1N1 pandemic hit children and teenagers harder than typical seasonal influenza[8] and was shown to be sustainable among populations of young people[17].

Finally, the mouth guard may offer some unexpected benefits. For example, kendo students may object to the stuffiness of the mouth guard during the summer. However, the mouth guard was intended for use mainly during the flu season, which overlaps with winter months, and kendo students may then appreciate the heat insulation. Prevention of flying spittle during *tsuba-zeriai* is another side benefit. Of more practical interest, we note that the gray-tinted version of the mouth guard obscured the wearer's lower field of vision. This appeared problematic for those participants in our study who had a habit tilting the head back. Although we did not analyze this aspect of the mouth guard objectively, we suggest that it may encourage such athletes to correct their posture by bringing the head forward so that they expand their field of vision over the mouth guard.

V. **Conclusion**

In conclusion, because we did not include a control group, we cannot comparatively

analyze the health benefits of added hand-washing, gargling, and introduction of the mouth guard in kendo practices; however, all of the participants in our study avoided influenza and other serious illnesses while using these preventive measures. The expected benefits of such a regimen should extend to prevention of all droplet-transmitted diseases including different strains of influenza and common colds. Although participants objected to the stuffiness of the mouth guard at first, most of them grew fully accustomed to it, and the discomfort should be minimized by introducing the mouth guard during colder weather at the beginning of the flu season. Participants in our study became so accustomed to the mouth guard that many continued to wear it after the completion of the study, and several continued to wear it well beyond the end of the flu season. (The first author would like to note that she has not suffered a cold in the 15 months since introduction of the mouth guard.) We therefore suggest other kendo clubs, especially those which include children and teenagers, to consider the introduction of established measures like hand-washing and gargling as well as use of a mouth guard in lieu of a face mask during practices.

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