

Supplying water to participants in midsummer *kendo* training camp: A study on the prevention of heat illnesses

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Abstract

Despite classification as an indoor sport, *kendo* suffers a high rate of heat illnesses and occasional deaths due to heat stroke. We undertook this study as an attempt to increase water intake of participants in *kendo* practices, including summer training camp practices, and thereby reduce the risk of contraction of heat illnesses.

This study followed 18 members of a men's collegiate *kendo* team during 26 regular summer practices and 5 summer training camp practices. We recorded WBGT and tracked changes in body mass and water intake of participants during each practice. Our analysis included amount of sweat, rehydration levels and differences between trends in lowerclassmen and upperclassmen.

We saw dependencies of amounts of sweat and water intake on WBGT and found that underclassmen had significantly lower rehydration levels than upperclassmen during regular practices in the high risk WBGT zone. We believe we were able to eliminate this discrepancy during training camp practices by 1.) issuing verbal advisories, 2.) adding water breaks, and 3.) supplying athletes with drinking containers with straws. However, overall, rehydration levels remained much lower than suggested levels (around 80%) for sustained performance, and athletes regularly lost more than 2% of total body mass during practices.

Keywords : safety in collegiate *kendo*, heat illnesses, sports and dehydration, *kendo* training camp, athletic performance

I. Introduction

Heat illnesses occur when the body loses its ability to regulate internal temperature, usually as a result of physical activity in hot environments, and are often associated with high heat, high humidity, intense radiation, and poor ventilation^{2,15,20}. Increase of water intake is a vital step towards prevention of heat illnesses. In addition to replacing fluid lost in sweat, water also acts as a heat sink, absorbing heat upon ingestion. Research shows that drinking water more often is an effective means of suppressing dangerous increases internal temperature^{3,12,18,21}. This is particularly important to athletes, because condition and performance may deteriorate before more serious symptoms occur^{1,10,14,22,23}. Therefore, water breaks during practices are important for both safe and effective practices⁹.

Records show that *kendo* ranks high among indoor sports for rate of heat illnesses^{9,15}. One explanation is that participants must wear about 5-6kg or more of hot, stuffy protective equipment that runs counter to heat-illness prevention guidelines¹². This equipment inhibits the body from shedding excess heat and may cause *kendo* practitioners to sweat more than athletes in other sports⁷. Furthermore, the tradition of disciplining the body and spirit means that *kendo* practitioners often train in extreme environmental conditions, as in midsummer practices without air conditioning, and in some places it is still customary to limit or even forgo water intake during practices regardless of conditions¹. Because of this custom, *kendo* instructors may be less likely than instructors of other sports to enforce proper water intake.

However, instructors need to take ample precaution because risk of heat illnesses varies greatly among individuals. People at elevated risk include those who are overweight, unaccustomed to activity in hot environments, have fever or diarrhea, or have previously lost consciousness in hot conditions. Among high school students, deaths are concentrated in male underclassmen⁹. Coupled with prevalent upperclassmen-lowerclassmen social interactions, we feel there are valid concerns that especially underclassmen may be at risk for heat illnesses.

The present study is an attempt to improve the method of supplying water to athletes during *kendo* training camp in hot, midsummer conditions, and thereby increase individual water intake and prevent heat illnesses. Because the contraction of heat illness by any individual is unacceptable, we investigated participants' individual water intake and sweat amounts during practice sessions, and analyzed individual ratios of sweat to body mass and ratios of water intake to sweat. We looked for individual trends as well as differences between upperclassmen and lowerclassmen.

II. Methods

1. Subjects

Participants were 18 members of the Gifu University Men's *Kendo* Team (4 seniors, 5 juniors, 4 sophomores, and 5 freshmen). They gave their voluntary consent to participate in all required measurements. To maintain anonymity, we assigned each participant a letter, A through R, so that seniors were assigned A through D, juniors E through I, sophomores J through M, and freshmen N through R. In other words, upperclassmen (seniors and juniors, n=9) were assigned A through I, and lowerclassmen (sophomores and freshmen, n=9) were assigned J through R.

2. Practice schedule and content

We conducted measurements during 26 regular practices, June 17, 2008 - August 4, 2008, and during summer training camp practices, August 9 - 11, 2008, shown in Table 1. Regular practices lasted approximately 120 min and were held on weekday afternoons (Wed: 16:00-18:00, Mon., Tues., Thurs., Fri: 17:00 - 19:00), and Saturday mornings (June 21 and 28, July 5, and August 2, 09:30 - 11:30). Training camp practices were held mornings and afternoons, from the afternoon of August 9 until the afternoon of August 11, for a total of 5 practices. Practice lengths varied as shown in Table 1.

Regular practices lasted approximately 120 min and consisted of warm-up (*taisou*: approximately 10 min), basic strike practice (*kihon renshuu*: approximately 20 minutes), mock competition practice (*shiai-geiko*: approximately 40 min), free bouting (*gokaku-geiko*: approximately 30 min), and instance strike practice (*kakari-geiko*: approximately 10 min). The first training camp practice lasted approximately 60 minutes and consisted of warm-up (10 min), basic strike practice (15 min), paired bouting (*mawari-geiko*: 18 min), and intense strike practice (5 min). Morning training camp practice on August 12 and 13 lasted approximately 120 min and consisted of warm-up (10 min), basic strike practice (20 min), skill practice (*waza no renshuu*: 20 min), free bouting (30 min), and intense strike practice (10 min). Afternoon training camp practices lasted approximately 180 min and consisted of warm-up (10 min), mock competition practice (120 min), free bouting (30 min), and intense strike practice (15 min).

3. Method of supplying water

Beverages were available to participants before all practices and at certain times during practices as indicated in Table 1. Participants drank from graduated cups during 10-min set rest periods and as needed between bouts or matches during free bouting and mock-competition practice. During training camp practices, they were also given additional short water breaks as shown in Table 1. During these short breaks, participants used straws and drank without removing the mask (*men*).

Some studies suggest that sports drink may increase fluid intake compared to water^{16,17}. Accordingly, in our study, regular practice beverages consisted of a choice of water and sports drink (O. Company) diluted with water to half the original concentration. Training camp beverages consisted of sports drink diluted to half the original value. All beverages were chilled to 7-10°C.

Table 1. Practice durations and voluntary water breaks.

Practice Type	Date	Duration	Water before practice?	Number of full (10min) water breaks	Number of short (5min) water breaks	Water between bouts or matches?
Regular	June 17 - August 4	120 min	Yes	3	0	Yes
Training Camp	August 11: afternoon	60 min	Yes; 500 ml encouraged.	0	3	No
	August 12 - 13: mornings	120 min	Yes; 500 ml encouraged.	3	1	Yes
	August 12 - 13: afternoons	180 min	Yes; 500 ml encouraged.	0	1	Yes

4. Measurements and Calculations

A. Wet-Bulb Globe Temperature

The wet-bulb globe temperature (WBGT) provides an index for comparing environmental heat stress across practice sessions and employing guidelines for both indoor and outdoor sports. We measured the WBGT with a WBGT-101 system (Kyoto Electronics Manufacturing, Co., LTD.) at 5-minute intervals during all practice sessions and applied the classification scheme of the Japan Sports Association for prevention of heat illnesses⁹.

B. Water Intake

We recorded water intake (the total intake of supplied beverages) directly before practices and during rest periods and breaks to the nearest 50ml for each participant.

C. Body Mass

We used an Innerscan 50 scale (Tanita Corporation) to measure the body mass of each participant before and after each practice session.

5. Calculations

In order to investigate amounts of sweat and rehydration level, we used the measurements of participants body mass before and after practice sessions and water intake to calculate amount of sweat, ratio of sweat to body mass, ratio of water intake to body mass, ratio of water intake to sweat (hereafter referred to as rehydration level, REH, as employed by Yoshida et al.²³), and percent decrease in body mass. We also calculated hourly rates of water intake and sweat during practice sessions. The calculations were as follows:

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

Ratio of sweat to body mass [%] = {amount of sweat [kg] / body mass before practice [kg]} × 100

Ratio of water intake to body mass [%] = {water intake [kg] / body mass before practice [kg]} × 100

Rehydration level [%] = {ingested water [kg] / perspiration [kg]} × 100

Percent decrease in body mass [%] = {(body mass before practice [kg] - body mass after practice [kg]) / body mass before practice [kg]} × 100

6. Individual advisories and communication of results to the participants

On August 4, after completion of the regular practices but before the training camp practices, we informed participants of the results of data collected thus far. In consideration of the risks of heat

illnesses, we also gave individual advisories to participants with particularly low mean rehydration levels ($< 30\%$) for practices in the high risk WBGT zone. We instructed these individuals to proactively drink more water during the upcoming training camp practices, and that failure to do so could be dangerous. We also instructed all individuals to aim at drinking 500 ml at the start of each training camp practice – which is a common protocol¹² – although compliance was voluntary.

7. Statistical Methods

We used Stat View 5.0 software to perform statistical analysis of amount of water ingested, amount of sweat, ratio of sweat to body mass, rehydration level, and percent body mass lost. In the results, we report the mean and standard deviation of measurements. We used the Pearson correlation coefficient to investigate trends dependent on WBGT and used the Mann-Whitney U-test to compare data between upperclassmen and lowerclassmen.

III. Results

1. WBGT

A. Regular practices

With some fluctuations, the mean \pm standard deviation WBGT of regular practices ranged from a low of $23.2 \pm 0.13^\circ\text{C}$, recorded on June 19, to a high of $29.8 \pm 0.38^\circ\text{C}$, recorded on August 4. WBGT tended to increase over the course of the regular practices as visible in Figure 1. During practices from June 17 through June 26, and on July 1 and July 3, mean WBGT fell in the caution (*chuuji*: $21 - 25^\circ\text{C}$) zone of the Japan Sports Association's classification scheme⁹. During practices on June 27, July 2, and from July 4 through July 11, mean WBGT fell in the moderate risk (*keikai*: $25 - 28^\circ\text{C}$) zone, and during practices from July 15 until August 4, mean WBGT fell in the high risk (*genjuu keikai*: $28 - 31^\circ\text{C}$) zone, as shown in Figure 1.

B. Training camp practices

The mean \pm standard deviation WBGT of practices during the training camp ranged from a low of $27.2 \pm 0.4^\circ\text{C}$, recorded the morning of August 10, to a high of $29.8 \pm 0.22^\circ\text{C}$, recorded the afternoon of August 11. Mean WBGT of all training camp practices fell in the high risk zone, except for the morning of August 10, which fell in the moderate risk zone, as visible in Figure 1.

2. Ratio of sweat to body mass

We analyzed ratio of sweat to body mass according to WBGT as shown in Figure 2. During regular practices, ratio of sweat to body mass was positively correlated to WBGT ($r=0.836$, $p<0.0001$).

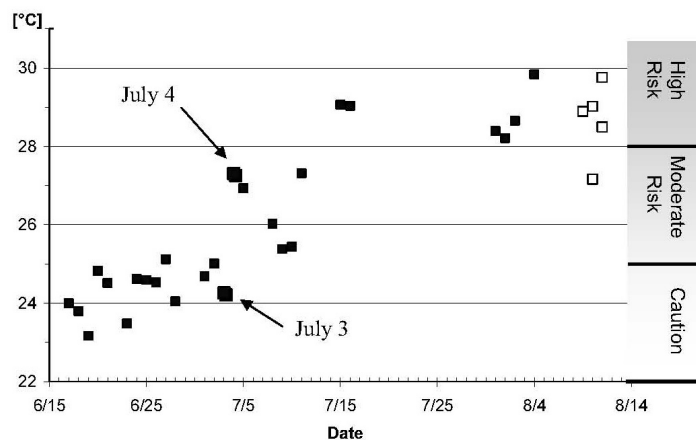


Figure 1. WBGT as a function of practice date. Regular practices are denoted by filled points. Training camp practices are denoted by open points. The right side of the graph indicates guidelines adopted by the Japan Sports Association for prevention of heat illnesses. WBGT increased through June and July and remained in the high risk zone for the last six regular practices and four out of five training camp practices.

For regular practices, mean \pm standard deviation ranged from $2.22 \pm 0.87\%$ to $2.94 \pm 0.83\%$ during caution-zone practices, increasing to a range of $2.67 \pm 0.89\%$ to $3.64 \pm 0.63\%$ during moderate-risk practices, and a range of $3.08 \pm 0.14\%$ for high-risk practices.

During training camp, ratios of sweat to body mass ranged from a mean \pm standard deviation of $3.167 \pm 0.73\%$ (during the shorter-length, 60-min practice on August 9) to $4.71 \pm 0.94\%$, also shown in Figure 2.

The results of our investigation into differences between upperclassmen and lower classmen are shown in Figure 3 according to WBGT zone. We saw no significant differences between these two groups during regular practices, nor during the training camp.

3. Ratio of water intake to body mass

We analyzed ratio of water intake to body mass according to WBGT as shown in Figure 2. During regular practices, ratio of water intake to body mass was, like sweat, positively correlated to WBGT ($r=0.830$, $p<0.0001$). For regular practices, mean \pm standard deviation intake ranged from $0.39 \pm 0.33\%$ to $0.80 \pm 0.43\%$ of body mass during caution-zone practices, increasing to a range of $0.59 \pm 0.22\%$ to $1.08 \pm 0.52\%$ during moderate-risk practices, and a range of $0.84 \pm 0.60\%$ to $1.35 \pm 0.46\%$ for high-risk

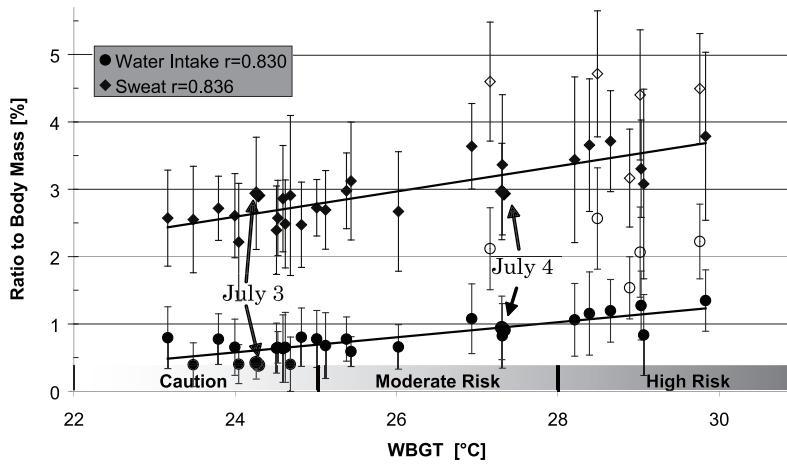


Figure 2. Ratio of sweat to body mass (diamonds) and ratio of water intake to body mass (circles) as a function of practice WBGT. Filled points indicate regular practices, and open points indicate training camp practices. Error bars represent standard deviation of participants' ratios. During regular practices, both sweat and water intake were correlated to WBGT as indicated by the black trend lines ($r = 0.836$ and $r=0.830$, respectively).

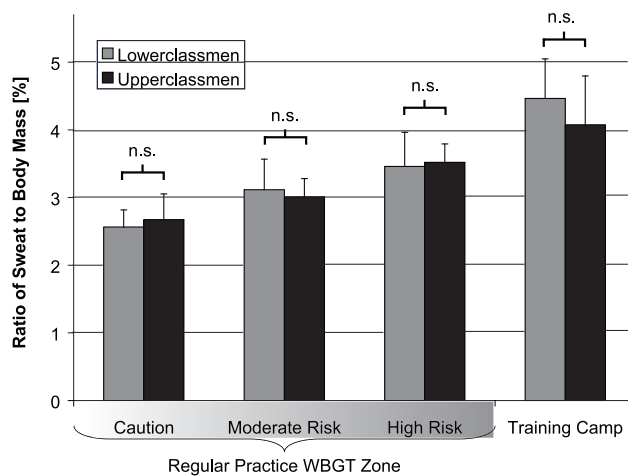


Figure 3. Comparison of ratios of sweat to body mass for lowerclassmen and upperclassmen. Data is divided into regular practice WBGT zones and training camp practices. Error bars represent standard deviation of participants' ratios. n.s.: No significant differences ($p<0.05$) were found between lower- and upper-classmen with a Mann-Whitney U test.

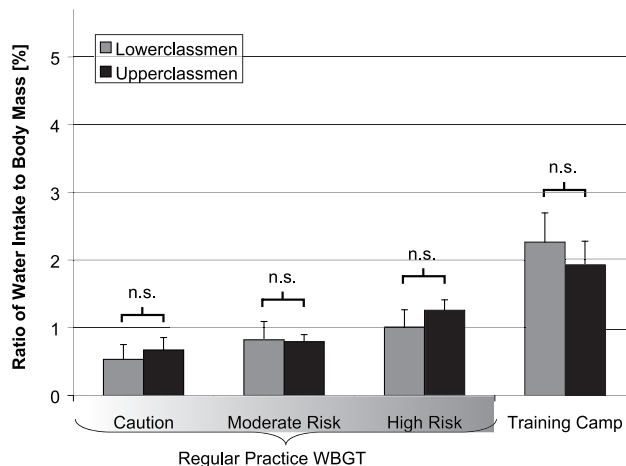


Figure 4. Comparison of ratios of water intake to body mass for lowerclassmen and upperclassmen. Data is divided into regular practice WBGT zones and training camp practices. Errorbars represent standard deviation of participants' ratios. n.s.: No significant differences ($p < 0.05$) were found between lower- and upper-classmen with a Mann-Whitney U test.

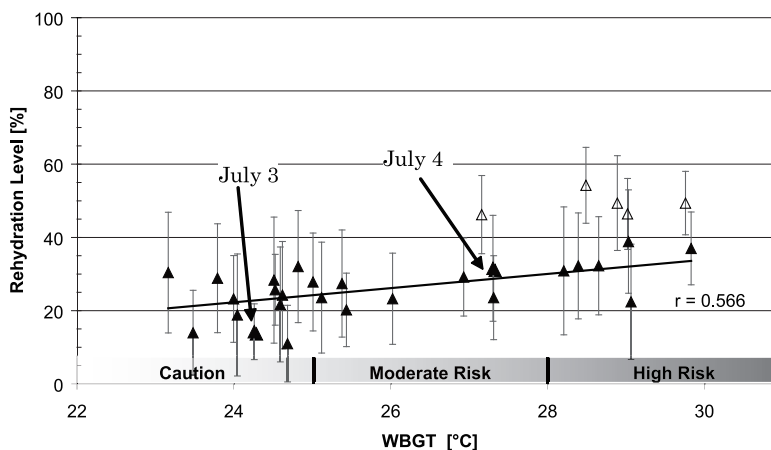


Figure 5. Ratio of water intake to sweat (rehydration level) as a function of practice WBGT. Filled points indicate regular practices, and open points indicate training camp practices. Error bars represent standard deviation of participants' rehydration levels. During regular practices, rehydration levels correlated to WBGT as indicated by the black trend lines ($r = 0.566$, $p = 0.002$).

practices.

During training camp, ratios of water intake to body mass ranged from a mean \pm standard deviation of $1.54 \pm 0.46\%$ to $2.57 \pm 0.75\%$, also shown in Figure 2.

The results of our investigation into differences between upperclassmen and lower classmen are shown in Figure 4 according to WBGT zone. We saw a slight tendency for underclassmen to have lower ratios of water intake to body mass in the caution and high risk zones during regular practice, but the difference was not significant and the trend was reversed during training camp practices.

4. Ratio of water intake to sweat (Rehydration level)

We analyzed water rehydration levels according to WBGT, and the results are shown in Figure 5. For regular practices, the correlation coefficient of rehydration level and WBGT was $r = 0.566$ ($p = 0.02$). For regular practices, rehydration levels of the population ranged from a mean \pm standard error of $27.8 \pm 13.4\%$ to $32.0 \pm 15.3\%$ during caution-zone practices, increasing to a range of $20.2 \pm 10.0\%$ to $31.6 \pm 14.5\%$ during moderate-risk practices, and a range of $22.4 \pm 15.7\%$ to $38.9 \pm 14.1\%$ for high-risk practices. Individual variations for high-risk regular practices were used as a basis for advising individual participants on water intake before the training camp. As shown in Figure 6, there were seven

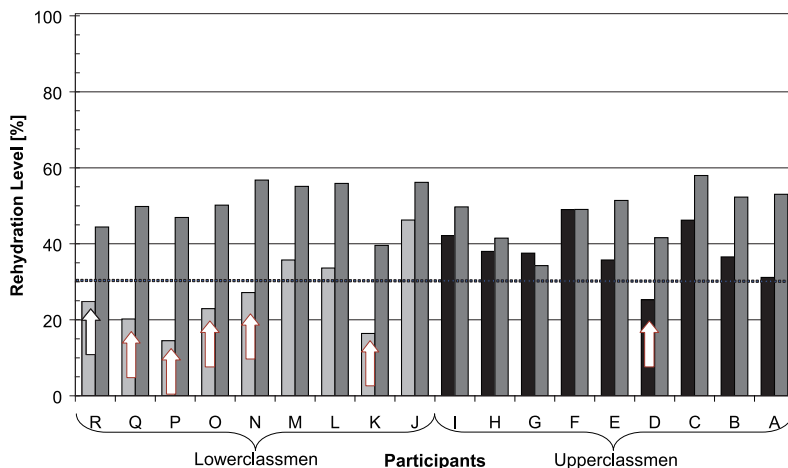


Figure 6. Rehydration levels for individual participants (Lowerclassmen: R-J, Upperclassmen I-A) during regular practices in the high risk WBGT zone (left columns) and during training camp practices (right columns). The seven individuals (denoted by arrows) with mean rehydration levels less than 30% (dashed line) during regular camp practices were given verbal advisories to increase water intake during training camp practices.

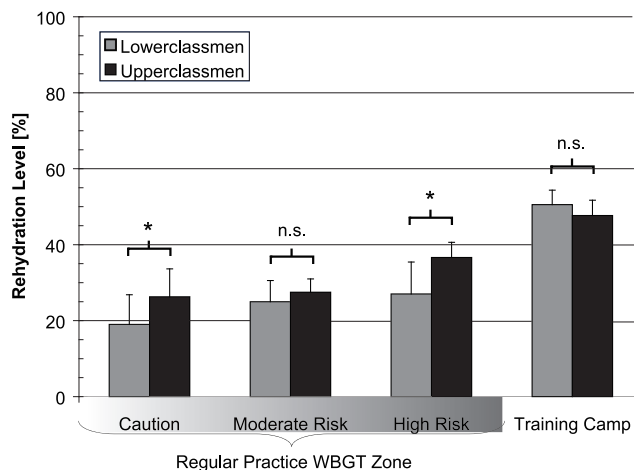


Figure 7. Comparison of rehydration levels for lowerclassmen and upperclassmen. Data is divided into regular practice WBGT zones and training camp practices. Error bars represent standard deviation of participants' ratios. Significant differences (*, $p < 0.05$, Mann-Whitney U test) were found between lower- and upper-classmen in the caution and high risk zones. This trend disappeared during training camp practices. n.s.: No significant difference.

participants with ratios of water intake to sweat of less than 30%, whom we advised to drink more during practices.

During training camp, rehydration levels of the population ranged from a mean \pm standard deviation of $46.2 \pm 10.7\%$ $54.2 \pm 10.4\%$, as shown in Figure 5. Individual rehydration levels were as shown in Figure 6. A Wilcoxon signed rank test showed that rehydration levels were greater during training camp practices than during regular practices, with significance $p = 0.003$; however, we must stress that there was some degree of variation of practice contents, conditions, and especially durations between regular and training camp practices.

The results of our investigation into differences between upperclassmen and lower classmen are shown in Figure 8 according to WBGT zone. We saw that the ratio of water intake to sweat was less ($p < 0.05$) for underclassmen than for upperclassmen during regular practices in all three zones, and this difference was significant ($p < 0.05$) for practices in both the caution zone and the high-risk zone. However, during the training camp practices, there was no significant difference and this tendency disappeared.

5. Percent decrease in body mass

We analyzed percent decrease in body mass according to WBGT, and the results are shown in Figure 8. The correlation coefficient was $r=0.514$ ($p=0.006$). For regular practices, percent decrease in body mass ranged from a mean \pm standard error of $1.67 \pm 0.52\%$ to $2.52 \pm 0.72\%$ during caution-zone practices, increasing to a range of $1.95 \pm 0.39\%$ to $2.56 \pm 0.52\%$ during moderate-risk practices, and a range of $2.03 \pm 0.67\%$ to $2.52 \pm 0.71\%$ for high-risk practices.

During training camp, percent decrease in body mass of ranged from a mean \pm standard deviation of $1.63 \pm 0.59\%$ to $2.48 \pm 0.75\%$, as shown in Figure 8.

The results of our investigation into differences between upperclassmen and lower classmen, shown in Figure 9 according to WBGT zone, revealed no significant differences between groups during regular practices, nor during the training camp.

IV. Discussion

1. Response to WBGT

Over the course of the study, WBGT tended to rise as summer advanced, so that the last six regular practices and four out of five training camp practices were held in the high risk zone. This indi-

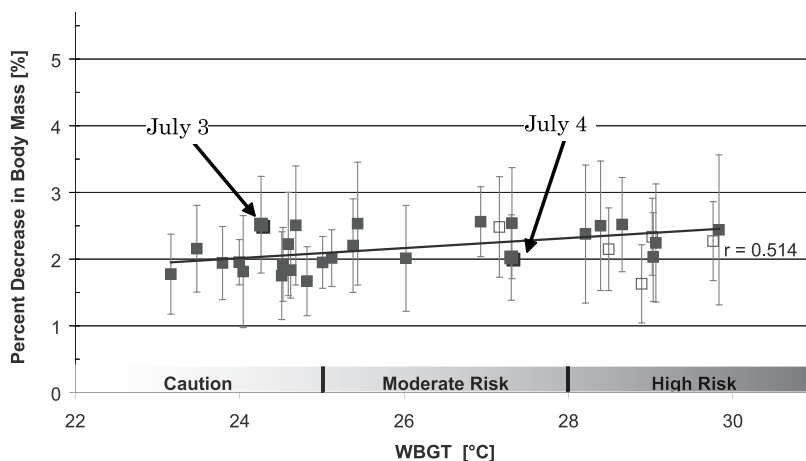


Figure 8. Percent decrease in body mass as a function of practice WBGT. Filled points indicate regular practices, and open points indicate training camp practices. Error bars represent standard deviation. During regular practices, percent decrease in body mass correlated to WBGT as indicated by the black trend lines ($r=0.514$, $p=0.006$).

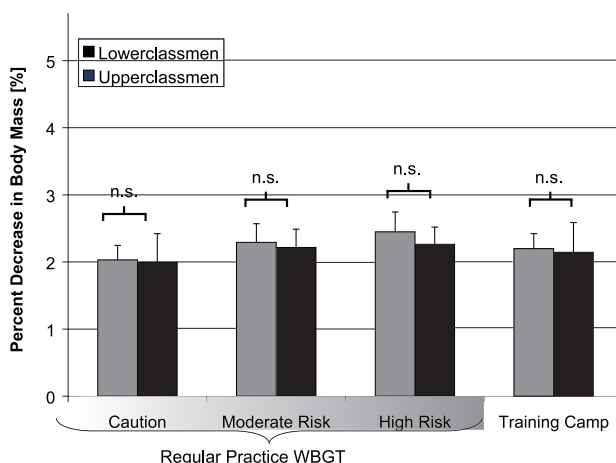


Figure 9. Comparison of percent decrease in body mass for lowerclassmen and upperclassmen. Data is divided into regular practice WBGT zones and training camp practices. Errorbars represent standard deviation. n.s.: No significant difference. We saw no significant difference between lower- and upper-classmen in any WBGT zone, although there was a slight (not significant) overall tendency for lowerclassmen to lose more percent body mass than upperclassmen.

cates high heat stress, and we infer that practice activities occurred in intense environmental conditions associated with a high risk of heat illnesses. Correlation of both ratios of sweat and water intake to body mass with WBGT are in line with research by Nakai et al.¹⁶, who saw correlation of sweat rate and amount of water consumption with WBGT during baseball training. This shows adjustment of the participants' bodies to heat stress and, in our study, resulted in a weakened correlation coefficient between rehydration level and WBGT.

However, on days of sudden increase in WBGT, such as July 4, we find exceptions. On July 4, the WBGT increased by approximately 3 degrees (Figure 1). Ratio of water intake to body mass showed that athletes were drinking more on July 4 than the previous day, but they did not sweat more (Figure 2). I.e., water retention increased and increased water intake did not equate to increased sweat. We believe that athletes were therefore especially prone to heat illnesses on such days. In such cases rehydration levels would increase without implying benefit to the athlete. As stated, increasing ingestion of water is important for preventing dehydration and heat illness; however, these results demonstrate that, after sudden increases in WBGT, drinking more water may be less effective against heat illnesses. Nakai et al. also reported an association between cases of severe heat disorders and abrupt increases in WBGT¹⁵.

This is important information for anyone exercising in variable climates and especially for coaches and instructors. The increase of centrally air-conditioned homes may lead to less acclimatization to heat and leave individuals more prone to heat illnesses during physical activity in environments without air-conditioning. This may explain the increase in reported deaths due to heat illnesses which began in the late 1970s⁹. Lack of acclimatization may contribute to a high rate of accidents on the first day of training camps²⁰. Gradual acclimatization over a number of days is a common theme in sports and work guidelines¹², but, as our results demonstrated, sudden increases in WBGT do not allow athletes to gradually acclimatize and can be especially dangerous.

2. Differences between upperclassmen and lowerclassmen

Because of differences in WBGT and practice lengths and conditions, in this report, we omit analysis and discussion of direct comparisons of amounts of water intake and sweat between regular practices and training camp practices. However, we do include a comparison between upperclassmen and lowerclassmen.

During regular practices in the high risk zone – when it is especially important to maintain measures against heat illnesses – we found a significant discrepancy between water rehydration levels of underclassmen and upperclassmen. Kamide⁸ found a similar discrepancy with underclassmen having significantly lower rehydration levels than upperclassmen during a *kendo* training camp in 2003. Concern about lower rehydration levels of six underclassmen and one upperclassman led us to verbally instruct these participants to increase water intake in training camp practices. Furthermore, we added water breaks beyond the conventional schedule and supplied participants with containers with affixed straws so that they could drink quickly and without the hassle of removing their masks. We attribute the apparent overall increase in rehydration levels during training camp and the disappearance of the underclassmen-upperclassmen rehydration gap to these measures (Figure 6).

3. Recommended rehydration and maintenance of body mass

Rehydration levels of approximately 80% are often suggested for sustained physical activity^{4,10,13,14}. However, none of our participants attained this level, despite our added measures – verbal advisories, added water breaks, and drinking containers with straws for ease of ingestion – during training camp practices. Yoshida et al.²³ found a correlation between rehydration level and aerobic performance. In another study, Yoshida et al.²² reported that although rehydration levels of 20% caused a decrease in maximum anaerobic power, rehydration levels of 40% and higher did not result in significant decrease. Recently, several other studies have indicated that for short-period activities, athletes may tend to opt for lower rehydration levels, and a rehydration level nearing 100% may be undesirable^{3,5}.

Loss of body mass is often used as a measure of dehydration detrimental to performance^{1,19}. A loss of 2% is has been stated as a guideline beyond various functions decline including aerobic performance^{14,19} and possibly mental performance^{6,19}. However, participants in our study regularly lost more than

2% of body mass (Figure 8-9), and such losses are comparable to those reported for other sports¹⁹. This may reduce athletes performance and the effectiveness of practices, so we believe further investigation and attempts to increase water intake are necessary.

V. Conclusion

We investigated changes in drinking and sweat patterns in athletes according to WBGT during regular and training camp practices and investigated differences between lowerclassmen and upperclassmen. We saw expected dependencies of sweat and water intake on WBGT; however, after sudden increases in WBGT amount of sweat failed to increase even though water intake did. Overall, participants regularly lost more than 2% body mass and did not approach suggested rehydration levels of 80% during any of the practices in our study. During regular practices in the caution and high risk WBGT zones, underclassmen had significantly lower rehydration levels than upperclassmen, but we were able to eliminate this difference during training camp practices.

We believe our results have several important implications for athletes and instructors. First, our results support the statement that sudden increases in temperature or WBGT represent especially dangerous situations for athletes until their bodies can adjust. Second, discrepancies in rehydration levels between lowerclassmen and upperclassmen may compound risks of heat illness if this behavior goes unchecked. However, we were able to overcome this issue by 1.) issuing verbal advisories, 2.) adding water breaks, and 3.) supplying athletes with drinking containers with straws so that they could drink more readily, and we offer these three steps to instructors facing similar concerns.

Despite this success, the participants in our study regularly exhibited low rehydration levels (<80%) and high dehydration levels (>2% loss of body mass) which have been linked to decreases in performance. We therefore feel that the topic of water supply to *kendo* athletes needs to be further pursued.

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