Motion Sickness Predictors in College Students and Their First Experience Sailing at Sea

Xinchen Zhang; Yeqing Sun

INTRODUCTION: Individual motion sickness susceptibility can be rapidly estimated by the motion sickness susceptibility questionnaire (MSSQ), but its stability is affected by various factors. The purpose of this study was to investigate the involved predictive factors of motion sickness screened with uniform samples of Chinese college students and to verify the individual susceptibility difference in marine navigation.

METHODS: A total of 1051 college students (719 men, 332 women; mean age: 18.32 ± 0.65 yr) completed the MSSQ. Another 42 men (mean age: 21.12 ± 1.10 yr) took part in 2 separate voyages. MSSQ data were collected before sailing and Graybiel motion sickness questionnaire (GMSQ) data were collected within 24 h after sailing and 24 h before landing.

RESULTS: The internal consistency of the MSSQ was 0.685. The mean subscore of the MSSQ-A (18.47 ± 19.49) was significantly higher than that of the MSSQ-B (12.69 ± 14.97). Women had significantly higher MSSQ scores (38.29 ± 33.49) than men (27.87 ± 30.27). The mean MSSQ score of the inland subjects (33.97 ± 33.35) was significantly higher than that of the coastal subjects (27.81 ± 29.24). Nearly 93% of new seafarers experienced seasickness during their first navigation. The MSSQ score was positively correlated with seasickness symptoms ($r = 0.706$).

CONCLUSION: Gender, age, and birthplace appear to be important predictors of motion sickness for Chinese college students. Specifically, women, younger people, and people who were born in inland China seem more prone to the syndrome. A high MSSQ score is a risk factor for seasickness. However, long-term voyages can lead to habituation, which reduces the occurrence of seasickness.

KEYWORDS: motion sickness susceptibility questionnaire, seasickness, individual susceptibility, college students.

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Motion sickness is a series of syndromes of autonomic reactions provoked by a variety of transport environments, especially during travel and virtual reality immersion.[17] The experience of motion sickness is often denominated by the type of provocative environment, which can cause seasickness, carsickness, airsickness, space sickness, simulator sickness, and virtual reality sickness, among others. Irrespective of environment, nausea and vomiting are the typical symptoms of motion sickness. Other related symptoms include stomach awareness, cold sweating, facial pallor, increases in salivation, sensations of bodily warmth, dizziness, drowsiness, headaches, loss of appetite, and increased sensitivity to odors. Motion sickness is very common, with about 90% of the general population having experienced motion sickness at some point in their lives.[11]

Previous studies have reported that about 25% of seafarers have experienced seasickness during usual sea conditions, and the proportion rises to 70% when suffering rough seas.[16] The high incidence of motion sickness hinders sailors and other related practitioners from consistently performing routine work tasks and can even reduce their survival rate. Therefore, the study of early warnings of motion sickness is of great significance to the health of these practitioners.

Individual susceptibility to motion sickness varies greatly and is affected by gender, age, and other factors.[19] Motion sickness is thought to be a result of gene-environment interaction,[22] so genetic factors may also play an important role in motion sickness susceptibility. A monozygotic and dizygotic twin

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concordance study by Reavley et al.[18] shows that the heritability of susceptibility to motion sickness is between 60–70%. Liu et al.[14] found that the genotype of the −1296 site on the α2-adrenergic receptor gene might be relevant to Asian hyper-susceptibility to motion sickness, but more direct data is needed to explain its mechanism. A recent large-scale genome study isolated 35 single nucleotide polymorphisms associated with self-reported carsickness from 80,494 individuals, suggesting that multiple genes are involved in the regulation of motion sickness.[10] However, the nature of the genes involved is not yet clear. Therefore, an effective and rapid method of sample classification is needed to further study the genetic factors of individual motion sickness susceptibility.

The most widely used method to predict the motion sickness susceptibility of an individual is the motion sickness susceptibility questionnaire (MSSQ), which was developed by Reason and Brand (1975) and validated by Golding.[4] The susceptibility to motion sickness is estimated by collecting and analyzing motion sickness experience data from different transport environments in two separate periods. It provides a tool to predict individual differences in motion sickness susceptibility caused by a wide variety of transport environments, including sea, land, air, and amusement rides.

The MSSQ scores might be influenced by complex experiences of motion exposure. The correlations between laboratory simulations of motion sickness and the MSSQ are frequently considered to be low. Golding[5] found that the predictive validity of the MSSQ evaluated by laboratory-controlled motion stimuli is median $r = 0.51$. The unreliability of laboratory motion stimulation might be one reason for the low correlations. Another possible reason is the difference in individual motion exposure experiences: because the subjects in previous studies had different living environments and a wide range of ages, occupations, and medical histories, their responses to the questionnaire may have little correlation.

In this study, we recruited freshmen from a university in China as our volunteers. They were all healthy young people without illness or medication histories. They also had similar life experiences; that is, they all had been in school for 12 yr before they went to college. This study had two main purposes. The first was to evaluate the motion sickness susceptibility distribution characteristics of Chinese college students using the MSSQ and to find involved predictive factors of motion sickness. The second was to verify the individual susceptibility differences in seasickness caused by maritime navigation to discover its predictors and to identify its possible moderating or protective factors.

METHODS

Subjects

In this study, a total of 1051 healthy college students (719 men and 332 women with an average age of 18.32 ± 0.65 yr) from Dalian Maritime University (Liaoning, China) were selected and given the MSSQ questionnaires. Another 42 students (men, mean age: 21.12 ± 1.10 yr) without navigational experience took part in the sailing experiment. All subjects verbally confirmed that they were healthy and did not use any medication. Before the experiment started, all subjects were fully briefed via an information sheet about the experimental procedure and notified that participation was voluntary, anonymous, and that their data were protected under relevant laws. They were also informed that they were free to quit the experiment at any time for any reason, with no penalty. We then obtained a written informed consent from each subject. This study was approved by the ethics committee of Dalian Maritime University, Liaoning, China.

Materials

A typical MSSQ questionnaire is divided into two parts with 54 items: Part A assesses the experience of motion sickness during childhood before the age of 12 (MSSQ-A score) and Part B evaluates the experience of motion sickness in the last 10 yr (MSSQ-B score). Both Parts A and B of the questionnaire collect information about how often the subjects felt sick or nauseated and vomited when exposed to the following forms of transportation and entertainment: cars, buses or coaches, trains, aircraft, small boats, ships, swings, roundabouts, and big dippers. The questionnaire is in Chinese and elicits the demographic details of age, gender, and hometown (birthplace). The calculation method is as follows: the higher the score, the more susceptible is the individual to motion sickness.[4]

$$\text{Part A: } MSSQAscore = \frac{2.64 \times (\text{total sickness score child}) \times 9}{(\text{number of types experienced as a child})}$$

$$\text{Part B: } MSSQBscore = \frac{2.64 \times (\text{total sickness score adult}) \times 9}{(\text{number of types experienced as an adult})}$$

$$\text{Total: } MSSQ\,score = MSSQAscore + MSSQBscore$$

The Graybiel motion sickness questionnaire (GMSQ) is a commonly used scale for assessing and rating symptoms of motion sickness in a clinic. It includes a wide range of signs and symptoms, such as cold sweating, pallor of varying degrees, increases in salivation, drowsiness, headaches, and even severe pain, as well as nausea and vomiting. To assess motion sickness severity, these main symptoms are assigned grades with associated scoring points as follows: N (0 point); MI (1 point); MIIB (2 to 3 points); MIIA (4 to 7 points); MIII (8 to 15 points); and F (16 points and higher). In addition, the cold sweating and pallor items can reach a maximum of 8 points.[8] The higher the score, the more serious the motion sickness is. The Graybiel method is easy for subjects to understand and is also available in Chinese language versions.

Procedure

The subjects for the first part of the experiment were all freshmen from Dalian Maritime University in China. The MSSQ questionnaires were provided to the subjects, who were divided into 6 groups of approximately 200 people each. They completed the questionnaire in a quiet classroom. The subjects were first told how to fill out the questionnaires, the significance of the study was explained, and they were asked to complete each questionnaire item accurately and truthfully. At the end of the informed consent process, they were given 20 min to fill out the questionnaires and provide their demographic information. When all the questions were completed, we uniformly retrieved the questionnaires.

Another 42 subjects took part in the maritime navigation test of this project. Our study was performed as part of the voyage of an annual training event for interns on the ship *YuKun*. All the volunteers were young men in the third year at Dalian Maritime University. Before they sailed, the subjects were recruited from a classroom to complete the MSSQ to report their motion sickness history. Then the first voyage started at 15:00 on November 21, 2016, and ended on December 3, 2016, lasting 12 d. At sea, the weather was generally clear and the sea state was degree 2∼3 (wave height: 0.5∼1.0 m) every day according to the ocean weather forecast reported by the Meteorological Bureau of Liaoning and Shandong Province. We collected the GMSQ data on the ship at 15:00 on days 2 and 10 (i.e., 24 h after sailing and 24 h before landing) to record their seasickness symptoms. The second voyage began at 09:00 on December 18, 2016, from the Port of Dalian and ended on December 25, 2016, lasting 7 d. The weather on the sea was calm during the first 3 d (the sea state was degree 2∼3), but the wind began to blow on the fourth day (the sea state was up to degree 5, wave height: 2.0∼2.5 m). Therefore, we collected the GMSQ data at 15:00 on days 2 and 5 as an additional stimuli group. The subjects were asked not to take any medication during the voyage.

Statistical Analysis

The MSSQ scores were calculated using the formula provided by Golding.[4] The higher the score, the more susceptible the individual is to motion sickness. A statistical analysis was completed using the IBM SPSS Statistics 19.0 program. The Kolmogorov-Smirnov and Levene tests were used to assess the normality and homogeneity of variance of the variables, respectively. The independent sample *t*-test, paired *t*-test, and one-way ANOVA analysis were used to investigate variable differences such as age, gender, hometown, MSSQ scores, and GMSQ scores. The linear mixed model was used to further analyze the impact factors and their interactions. The correlations between the MSSQ-A (childhood part) and MSSQ-B (adult part) scores and between the MSSQ and GMSQ scores were all assessed by Pearson's correlation coefficient. The constituent ratios of subjects in the different motion sickness severity groups on the two voyages were compared by Chi-squared analysis. Sample statistics and odds ratios with 95% confidence intervals (CI) were computed to assess the relationships between the study factors. Differences were considered significant if the *P*-value was < 0.05.

RESULTS

A total of 1174 MSSQ questionnaires were distributed to the students and 1070 of them were collected: a retrieval rate of 91.1%. Of them, 1051 questionnaires were verified to be valid after screening, indicating an effective retrieval rate of approximately 98.2%. Questionnaires were deemed valid in this study if the following three criteria were met: the necessary personal information was included, all the questions in the main part were completed, and the MSSQ score was within a reasonable range. **Table I** lists all the demographic characteristics of the subjects for this part and percentages of the variables. There were no statistically significant between-group differences for age, gender, or birthplace.

The mean MSSQ score was 31.16 ± 31.68, with a positively skewed distribution. The median (50th percentile) score was 22.68, the 25th percentile was 5.02, and the 75th percentile was 47.52. In this study, we defined the level of susceptibility to motion sickness by the percentile of the MSSQ score: a less than median score (22.68) was designated mild susceptibility, a median (22.68) ∼75th percentile score (47.52) was moderate susceptibility, and a greater than 75th percentile score (47.52) was severe susceptibility. Based on these criteria, we obtained 525 mildly susceptible subjects, 267 moderately susceptible subjects, and 259 severely susceptible subjects, as shown in **Table II**.

The mean subscore of the MSSQ-A (child) was 18.47 ± 19.49, which was significantly higher than 12.69 ± 14.97 of the MSSQ-B (adult) ($t = 7.629$, $P < 0.001$), indicating that people are more susceptible to motion sickness in childhood (< 12 yr). The internal consistency of the MSSQ was expressed by the correlation between the MSSQ-A (child) and MSSQ-B (adult) scores, which were found to be significantly correlated ($r = 0.685$, $P < 0.001$), as shown in **Fig. 1**. This suggests that the susceptibility trends of children and adults are essentially the same.

An independent sample *t*-test was performed on the differences of the MSSQ scores between men and women. The results show that the mean MSSQ score of women (38.29 ± 33.49) was significantly higher than that of men (27.87 ± 30.27,

Table I. General Characteristics of the Subjects in the First Part: Demographics and Percentages of the Variables ($N = 1051$).

		ALL SUBJECTS (1051)		AGE GROUP, YEAR					
				≤18		>18			
VARIABLE		***N***	**%**	***N***	**%**	***N***	**%**	χ^2	***P***
Age	18.32 ± 0.65	1051		696	66.22	355	33.78		
Gender	Men	719	68.41	466	64.81	253	35.19	2.024	0.155
	Women	332	31.59	230	69.28	102	30.72		
Hometown	Inland	571	54.33	379	66.37	192	33.63	0.013	0.909
	Coastal	480	45.67	317	66.04	163	33.96		

Table II. The Groups of Motion Sickness Susceptibility Classified According to MSSQ Score.

		ALL SUBJECTS (1051)		GENDER MEN (719), WOMEN (332)					
GROUPS	PERCENTILE SCORE	N	%	N	%	χ^2	P	MEAN MSSQ SCORE	SD
Mild	<median (< 22.68)	525	49.96	Men: 386 Women: 139	53.69 41.87	19.556	0.000	6.99	7.32
Moderate	median ~75th (22.68~47.52)	267	25.40	Men: 183 Women: 84	25.45 25.30			34.89	7.59
Severe	> 75th (> 47.52)	259	24.64	Men: 150 Women: 109	20.86 32.83			76.31	25.82

$t = 4.835$, $P < 0.001$), indicating that the susceptibility of women to motion sickness was higher than that of men. In childhood (MSSQ-A), women still showed higher susceptibility than men (MSSQ-A women's score = 21.84 ± 19.46; MSSQ-A men's score = 16.92 ± 19.31; $t = 3.832$, $P < 0.001$) and showed the same trend in adulthood (MSSQ-B) (MSSQ-B women's score = 16.45 ± 16.40; MSSQ-B men's score = 10.95 ± 13.94; $t = 5.297$, $P < 0.001$). The scores are shown in **Fig. 2**.

Based on the previous discussion, the subjects could be divided into mild susceptibility, moderate susceptibility, and severe susceptibility groups. The constituent ratios of susceptibility to motion sickness differed by gender ($\chi^2 = 19.556$, $P < 0.01$). It was found that the proportion of men in the mild susceptibility group (53.69%) was higher than that of women (41.87%). Conversely, the proportion of women in the severe susceptibility group (32.83%) was higher than that of men (20.86%), as shown in Table II, suggesting that women not only had a higher incidence of motion sickness, but also had more severe symptoms.

The subjects were from 30 provinces in China: 11 of them are on the coast and 19 are inland. There were 480 coastal subjects (mean age: 18.33 ± 0.64 yr) and 571 inland subjects (mean age: 18.30 ± 0.73 yr). **Fig. 3** shows that the mean MSSQ score of the subjects from inland provinces (33.97 ± 33.35) was significantly higher than that of the subjects from coastal provinces (27.81 ± 29.24, $t = 3.188$, $P < 0.01$). Whether in childhood (MSSQ-A inland = 19.98 ± 20.25; MSSQ-A coastal = 16.68 ± 18.39; $t = 2.764$, $P < 0.01$) or in adulthood (MSSQ-B inland = 14.00 ± 15.90; MSSQ-B coastal = 11.14 ± 13.64; $t = 3.139$, $P < 0.01$), the mean subscores of inland subjects were significantly higher than those of coastal subjects, indicating that inland subjects were more susceptible to motion sickness than coastal subjects.

A linear mixed model was used to analyze the impact factors of gender and hometown demographics. These two items were used as fixed effect factors to evaluate their multiple effects on motion sickness susceptibility. The model showed that the motion sickness rating (MSSQ score) could be significantly influenced by gender [$F(1,1048) = 27.018$, $P < 0.001$] and hometown [$F(1,1048) = 11.767$, $P = 0.001$]. Combined with the t-test and one-way ANOVA analysis, it can be seen that gender and birthplace could play important roles in predicting motion sickness; that is, women and subjects from inland China were more susceptible to motion sickness.

A total of 29 subjects took part in the first voyage, but one of them withdrew from the project due to personal reasons. The results show that the GMSQ score of the subjects on the second day was significantly higher than that on the tenth day (GMSQ score on day 2 = 6.52 ± 4.54, GMSQ score on day 10 = 4.33 ± 4.06, $t = 2.873$, $P < 0.01$). The MSSQ scores of the subjects were significantly and positively correlated with their GMSQ scores (r = 0.658 on day 2 and r = 0.647 on day 10, $P < 0.01$).

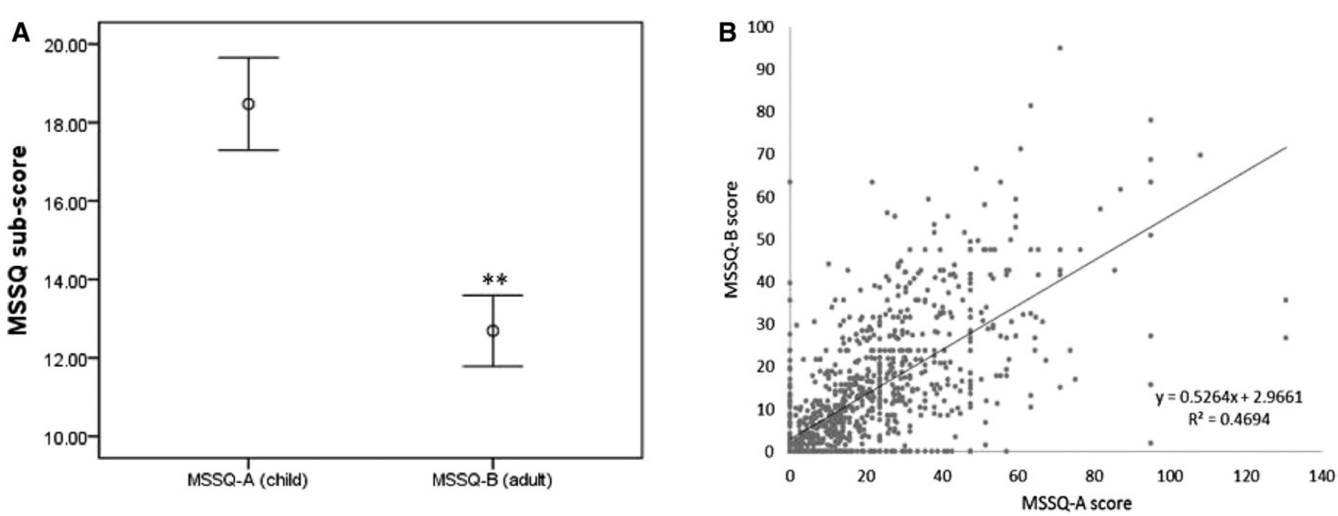

Fig. 1. A) The mean subscores of Part A (child) and Part B (adult) for all the samples. B) The correlation between MSSQ-A score (child) and MSSQ-B score (adult); $R^2 = 0.4694$ and r = 0.685. **$P < 0.001$ compared with the mean MSSQ-A score; error bars are 95% CIs. Number of subjects $N = 1051$.

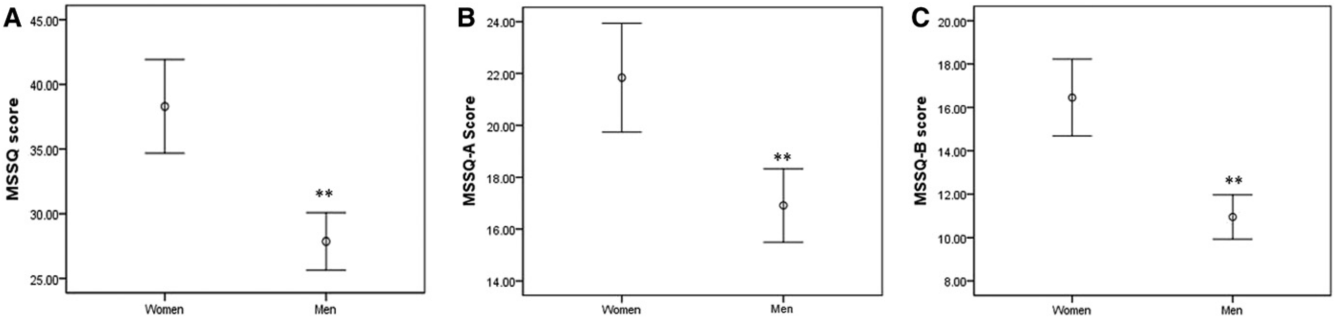

Fig. 2. Gender differences. A) The mean MSSQ scores of men and women. B) The mean MSSQ-A scores of men and women; and C) the mean MSSQ-B scores of men and women. **$P < 0.001$ compared with the mean MSSQ/MSSQ-A/MSSQ-B scores of women; error bars are 95% CIs. Number of men $N = 719$; number of women $N = 332$.

Another 15 young men took part in the second voyage. There were no significant differences in their GMSQ scores on days 2 and 5, but the scores on the fifth day were slightly higher (GMSQ score on day 2 = 7.88 ± 5.53, GMSQ score on day 5 = 8.00 ± 5.04), as shown in **Fig. 4A** and **B**. Also, their MSSQ scores were still significantly and positively correlated with their GMSQ scores (r = 0.772 on day 2 and r = 0.753 on day 5, $P < 0.01$). The correlation between MSSQ scores and reported seasickness was median r = 0.706.

Because the constituent ratios of the number of subjects in the different groups were not significantly different between the two voyages, the GMSQ data obtained in the first 24 h (day 2) were pooled for further analysis. When the subjects were divided into the mild, moderate, and severe susceptibility groups, the motion sickness symptoms (mean GMSQ score) of each group tended to increase (mean GMSQ score of mild susceptibility group = 4.13 ± 3.20; moderate susceptibility group = 7.39 ± 4.29, $t = -2.489$, $P < 0.05$; severe susceptibility group = 11.88 ± 5.22, $t = -4.522$, $P < 0.01$), as shown in **Fig. 4C**. These results suggest that a higher MSSQ score was a risk factor for seasickness.

DISCUSSION

Previous studies have shown that there are many factors influencing individual motion sickness susceptibility. Regarding age, motion sickness appears at about 6 or 7 yr, with a susceptibility peak at around 9 yr, then begins a long, gradual decline.[9] Women have been reported to be more susceptible to motion sickness than men, and they show higher incidences of vomiting and other symptoms of motion sickness.[12] Differences in motion sickness susceptibility have also been related to ethnic origin. Finley et al.[3] are of the view that Caucasian subjects have significantly higher tolerances than Chinese subjects when acutely exposed to a body rotation. The results of previous studies might have been influenced by the characteristics of the subjects. In this study, we selected healthy freshmen of Dalian Maritime University as the subjects to evaluate the distribution characteristics of motion sickness susceptibility of Chinese college students and its related factors. These subjects were of the same age stratum, had the same level of education, and had similar life experiences before attending college, which can reduce the interference of complex living environments and motion exposure experiences to some extent.

We collected a total of 1051 questionnaires from 719 men and 332 women, which was similar to the 2.3:1 gender distribution in this university. The mean MSSQ score of our subjects was 31.16 ± 31.68, which was lower than the norms given in the original MSSQ paper (45.5 ± 37.6), and the median score of 22.68 was even lower than the normative median of 40.[4] This may be due to the self-selection of the sample, as they were all students from a maritime college. Highly motion sickness-susceptible students may be more likely to opt for a different type of career to avoid seasickness. A study of the highly provocative environment of zero-gravity flights observed a similar type

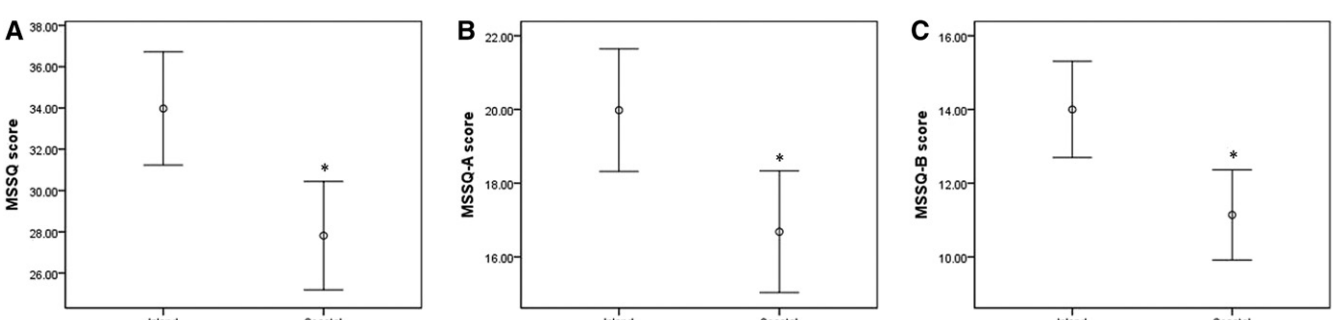

Fig. 3. A) The mean MSSQ scores of subjects from inland and the coast. B) The mean MSSQ-A subscores of inland and coastal subjects and C) the mean MSSQ-B subscores of inland and coastal subjects. *$P < 0.05$ compared with the mean MSSQ/MSSQ-A/MSSQ-B score of inland subjects; error bars are 95% CIs. Number of inland subjects $N = 571$; number of coastal subjects $N = 480$.

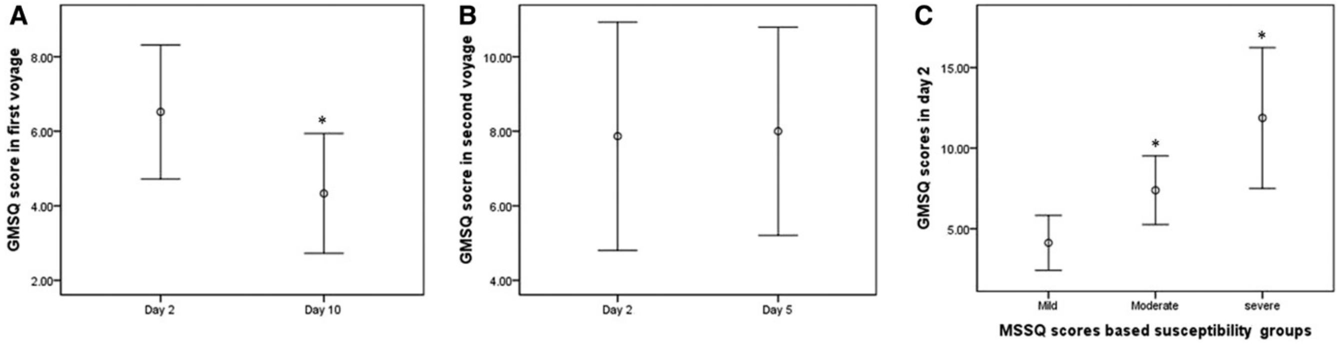

Fig. 4. The mean GMSQ scores of two separate voyages. A) The GMSQ scores of the first voyage on days 2 and 10. B) The GMSQ scores of the second voyage on days 2 and 5. For both A & B: *$P < 0.05$ compared with the mean GMSQ score of the first voyage on day 2; error bars are 95% CIs. Number of subjects on first voyage $N = 27$; number of subjects on second voyage $N = 15$. C) The mean GMSQ scores of subjects divided into different susceptibility groups (mild/moderate/severe). *$P < 0.05$ compared with the mean GMSQ score of the mild susceptibility group; error bars are 95% CIs. Number in mild group $N = 16$; number in moderate group $N = 18$; number in severe group $N = 8$.

of self-selection in fliers, in which people who are very susceptible to motion sickness tend to avoid going on such flights when possible.[7]

As we show here, the mean MSSQ score of women is significantly higher than that of men, and the subscores of the MSSQ-A and MSSQ-B for women are also significantly higher than those of men. It is shown that women are always more susceptible to motion sickness both in childhood and adulthood, which is consistent with previous studies.[13] Furthermore, because the subjects were assigned to different susceptibility groups (i.e., mild, moderate, and severe), we found that the distribution of genders was unbalanced. The proportion of women in the severe susceptibility group was higher than that of men, whereas the proportion of men in the mild susceptibility group was higher than that of women (see Table II). The results show that women were not only more susceptible to motion sickness, but also had more serious symptoms than men. The reports that women tend to be more susceptible to motion sickness are not just attributed to the self-report bias, as the questionnaire has objective item options for vomiting.[19] One possible explanation is that women are more susceptible due to different hormone regulation, but so far, this has not been confirmed. It also does not seem related to men experiencing more outdoor sports and motion environments, which can make them more habituated.[2]

The internal consistency between the MSSQ-A and MSSQ-B was good, and the correlation coefficient was $r = 0.685$. This suggests that the susceptibility trend in childhood and adulthood is essentially the same. The mean subscore of the MSSQ-A (child) was significantly higher than that of the MSSQ-B (adult), which is consistent with previous studies, showing that people have greater susceptibility in childhood.[15] Because their vestibular systems are not completely developed, infants and children under 2 yr of age are immune to motion sickness.[17] As previously mentioned, children become susceptible to motion sickness at about 6～7 yr of age and reach a peak around 9～10 yr.[20] However, the reasons for this are not clear. The beginning of puberty (around 10～12 yr) and the onset age of motion sickness susceptibility (6～7 yr) are not synchronized, implying that hormonal changes are not a direct reason for motion sickness susceptibility commencement.[6] Children start at Chinese elementary schools at the age of 6, where they begin to get in touch with new environments and motion stimuli and have more opportunities to be exposed to these potentially nauseogenic situations. This may be one reason why motion sickness susceptibility begins at the age of 6～7 in China.

As we have shown here for the first time, individual susceptibility to motion sickness is correlated with people's birthplaces. The subjects in this study come from 11 coastal and 19 inland provinces in China. The mean MSSQ score of inland subjects was significantly higher than that of coastal subjects. This may be because there are more types of transportation in coastal areas, such as ships and boats. In addition, coastal provinces in China are more developed than inland ones, with more playgrounds and fair rides. Therefore, the subjects from the coasts may have more experience with motion exposure and have more chances to become habituated due to the concentration of motion stimuli. Our results show that inland people in China are more susceptible to motion sickness. This might provide some indirect evidence of a genetic contribution to this difference.

Previous studies on the correlation between MSSQ scores and the symptom levels of motion sickness in transport environments have been insufficient. It is believed that different types of motion environments lead to different sensitivities in individuals. In this study, we focused on how sailing at sea affects individual susceptibility to seasickness and assessed the correlation between MSSQ-measured motion sickness susceptibility and seasickness symptoms during an actual voyage. As previously mentioned, symptom ratings of motion sickness were assessed by the GMSQ questionnaire and included cold sweating, pallor of varying degrees, increases in salivation, drowsiness, headaches, severe pain, nausea, and vomiting. A positive case of motion sickness was defined as having one or more of these symptoms and the absence of all symptoms was regarded as a negative case. None of our subjects had prior sailing experience and nearly 93% of them had some level of motion sickness symptoms within 24 h of boarding.

This high incidence of seasickness might be related to personal factors, such as a lack of experience and fear of the first navigation. The first voyage experiment lasted for 12 d. The GMSQ data of the subjects were collected on days 2 (within 24 h after sailing) and 10 (within 24 h before landing), and the results show that their GMSQ scores were significantly correlated with their MSSQ scores. The sea state during the whole voyage kept within degree 2～3, so the subjects were exposed to a lasting and stable motion stimulus the entire time. On the tenth day of the voyage, their mean GMSQ score at sea significantly decreased, showing that the seasickness symptoms obviously reduced. We thus speculate that the lasting low-frequency linear acceleration stimuli for 10 d of the voyage at sea may lead to habituation.[21]

The second voyage lasted for 7 d, with a calm sea state of degree 2～3 during the first 3 d, which began to worsen on the fourth day (degree 5). Taking this condition as an additional uncontrolled motion stimulus, we found that the seasickness symptoms of the subjects became more serious on day 5 and the mean GMSQ score also increased. The correlation between MSSQ scores and GMSQ scores was $r = 0.753$, which was much higher than that under the controlled motion stimuli reported in the laboratory ($r = 0.5$). This result indicates that the MSSQ questionnaire might better predict motion sickness in a real transportation environment than under laboratory stimulation. This may be because the items in the MSSQ ask about the incidence of motion sickness in different types of actual provocative environments. Furthermore, the subjects in this study had no experience of sailing at sea, which might provide a more accurate result.

The subjects were divided into mild, moderate, and severe susceptible groups via their MSSQ scores based on the data from the first part of the experiment. Because the constituent ratios of the subjects in different groups showed no significant differences between the two voyages, the GMSQ data obtained in the first 24 h (day 2) were pooled for further analysis. The GMSQ scores progressively increased with the increase of susceptibility and the MSSQ showed great potential in predicting individual susceptibility to motion sickness, indicating that higher MSSQ scores might be a risk factor for motion sickness. Chan et al.[1] report that the MSSQ questionnaire might be more useful in predicting motion sickness susceptibility in a nonseafaring group rather than in a seafaring group, which is similar to our findings. Therefore, to some extent, higher MSSQ scores can predict seasickness, especially for the first voyage of an individual. We need to expand our samples to verify this trend in future research.

In conclusion, the results of this study indicate that motion sickness susceptibility is affected by many factors such as age, gender, birthplace, and the environment in adulthood. Women, younger people, and people born or living in inland provinces are more susceptible to motion sickness among Chinese college students. In combination with the real sailing situation, the classification method that divided the subjects into mild, moderate, and severe susceptibility groups based on the MSSQ scores was feasible in this study. High MSSQ scores were found to be a risk factor of seasickness for those sailing for their first time, with nearly 93% new seafarers affected by seasickness. Therefore, the MSSQ appears to be good at predicting sensitivity to motion sickness in the real transport environment, especially when a person enters a new type of provocative environment. We also found that a long-term voyage in calm seas will lead to seasickness habituation. This might be a protective factor regarding seasickness, but the habituation would be weakened if the stimuli strength exceeds the threshold.

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