# Sea Voyage Training and Motion Sickness Effects on Working Ability and Life Quality After Landing

Rui-Rui Qi; Shui-Feng Xiao; Yang Su; Yu-Qi Mao; Lei-Lei Pan; Chen-Hui Li; Yi-Lin Lu; Jun-Qin Wang; Yi-Ling Cai

**BACKGROUND:** The effects of seasickness on working performance during motion exposure have been reported, while the aftereffects on working ability and life quality decline (WLD) still remain unclarified.

**METHODS:** Two cohorts of healthy male Chinese subjects received either a single (SSV) or repeated (RSV) sea voyage training program on different vessels. A seasickness incidence (SSI) questionnaire was administered to assess the prevalence of seasickness symptoms (vomiting, nausea, other, or no symptoms). A WLD questionnaire was used to survey the general feeling of WLD (severe, moderate, slight, and none) by a 4-point score as well as the incidence rate (IR) of specific WLD items within 24 h after landing.

**RESULTS:** The RSV cohort had lower overall IR of WLD than the SSV cohort (54.64% vs. 63.78%, $N = 657$ for both cohorts). The landing ship trainees in both cohorts showed higher general WLD score and higher IRs of physical fatigue, sleep disorder, and spontaneous locomotion decrement than those trained on the small vessels. Subjects with vomiting or nausea had higher general WLD score and higher IRs of concentration distraction, physical fatigue, anorexia, and spontaneous locomotion decrement than those with no symptoms. Higher IRs of firing accuracy decline (SSV: 21.35% vs. 7.13%, 9.14%; RSV: 22.11% vs. 9.28%, 5.27%), equipment operation disturbance (SSV: 16.85% vs. 3.57%, 6.85%; RSV: 20.47% vs. 7.85%, 7.03%) were also observed in the vomiting subjects than those with other symptoms and no symptoms.

**DISCUSSION:** Significant WLD after landing was associated with transportation types, seasickness severity, and habituation during sea voyage training.

**KEYWORDS:** sea voyage training, seasickness, working ability, life quality, transportation type.

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Motion sickness is normally defined as autonomic signs combined with unpleasant symptoms caused by unfamiliar motion (e.g., in boats, cars, and airplanes) in unadapted individuals.[31,38] There are several hypotheses that explain the development of motion sickness, but none of these theories fully clarify the precise mechanism. The widely accepted sensory conflict and neural mismatch theory postulated that motion sickness might be caused by the mismatch between sensed 'abnormal motion' information and internally stored 'experienced motion' memory built on Earth's gravity force.[1,38] Observation of the significant association between the development of seasickness and the difficulty in coupling of postural activity with ship motion in susceptible individuals supported the postural instability theory of motion sickness.[17,33] The evolutionary theory proposed by Claremont and Treisman suggested that motion sickness induced autonomic reactions such as nausea and vomiting were accidental byproducts of the evolutionarily conserved reflexes as a defense against neurotoxin ingestion.[17,29] Without appropriate treatment, motion sickness can commonly induce dizziness, pallor, sweating, yawning, paroxysmal salivation and stomach awareness, and ultimately cause recurrent nausea and vomiting. Motion sickness might also be the consequence of disturbances in the motion sensory systems (visual, vestibular, and proprioception) which trigger general stress responses and disrupt

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homeostasis regulation in the central nervous system.[6] Repeated or continued exposure to a type of motion could induce habituation, a phenomenon of decrement in susceptibility to that specific motion pattern.[36]

Previous studies have demonstrated that for some individuals motion sickness does impact work performance and cognition. Uncoupled virtual or real vertical motion could decrease cognitive performance, including math processing, two-hand tapping, grammatical reasoning, and code substitution tasks.[28] Similarly, verbal short-term memory performance declined in human subjects who experienced motion sickness induced by a rotating optokinetic drum.[10] Motion sickness induced by laboratory earth-vertical and horizontal linear oscillation impaired performance on a visual search task.[18] Additionally, the presence of motion sickness is associated with a significant decline in attention and concentration among medical attendants during air transport via helicopter and ground transport via hospital-owned ambulances.[37] A recent study showed that even mild motion sickness induced by superposition of three independent sinusoidal motions (heave, roll, and pitch) could potentially influence multitasking cognitive performance, including alphabet memory and arithmetic tasks or their composite.[27] On the other hand, short-term exposure (20 min) to a virtual reality game scene with navigation and shooting tasks could lead to a brief ataxia postexposure,[8] while 15–60 min virtual reality exposure generated postural instability which could last for 1 h postexposure.[5] A more recent study with 12 male adults who performed 30-min driving tasks in a truck simulator showed persistent oculomotor disturbances and disorientation postexposure until the evening of the training day.[12] These studies demonstrate that simulator sickness generated by a variety of real and virtual environments also induces adverse effects that continue well beyond the exposure.[15]

Seasickness, as the most prominent type of motion sickness, has become a common problem since human beings started to use manufactured transportations for trade or warfare at sea.[23] It is well-known that sea voyage training always cripples the ability of marine soldiers in the absence of organic injury. Working performance efficiency of sailors declined as a result of the interaction of the degree of seasickness and type of vessel.[11] Seasickness not only affects working performance, especially novel tasks and cognitive tasks that involve spatial orientation processing during the motion exposure period,[17] but also created serious problems in performance of warfighters' operational tasks during combat training exercises.[11] Nevertheless, the aftereffects of seasickness on military working ability and quality of life after landing are still unclear. In the present study we investigated the impact of short-term sea voyage training on the working ability and quality of life after landing in two cohorts of the Chinese marine corps receiving single or repeated sea voyage training programs. Particular emphasis was made on the potential contribution of transportation types, seasickness severity, and habituation on working ability and life quality decline (WLD) within 24 h after the end of training.

## METHODS

### Subjects

All subjects were active-duty healthy male Chinese marines ($N = 1720$, age: 18∼28 yr) who had no history of vestibular diseases, drug addiction, smoking habits, or long-term medication and declared no sea voyage experience before enlistment. This research complied with the Declaration of Helsinki and was approved by the Ethics Committee at the Naval Military Medical University (Shanghai, PR China). Informed consent was obtained from each participant in writing before participating.

### Questionnaires

The seasickness incidence (SSI) questionnaire included demographic items concerning age, height, weight, transportation type (warship: 1300–3000 tons of displacement; landing ship: 3000–5000 tons of displacement; and smaller vessels: less than 1000 tons of displacement). Sailors indicated either that they had no seasickness symptoms or that they experienced vomiting, nausea, or other symptoms (headache, dizziness, stomach awareness, salivation, yawning, drowsiness) during the voyage (**Table I**).

A 4-point Likert scale (severe - 4 points, moderate - 3 points, slight - 2 points, or none - 1 point) was used to respond to the general feels of WLD (general WLD score). Questions also included specific impaired WLD items (working ability: concentration distraction, physical fatigue, firing accuracy decline, equipment operation disturbance; quality of life: anorexia, sleep disorder, and spontaneous locomotion decrement) on land within 24 h after sea voyage training (**Table II**).

### Procedure

Our study was carried out during the period of a sea voyage training program launched by the marine corps. Those who declared that they had received repeated training sessions before this training program on different types of ships were not included ($N = 145$). There were 792 subjects who received a single sea voyage (SSV cohort) training session (initial training after enlistment) and 783 subjects who completed the third training session of a repeated sea voyage (RSV cohort) training program (the program involved 3 sessions separated by 3–6 mo) who completed the SSI survey (**Fig. 1**). Each training session was initiated at about 0800 and lasted about 6 h with the weather generally clear. The sea state was Degree 3 (wave height: 0.5–1.25 m) on the Douglas Sea Scale according to an ocean weather forecast reported by the Meteorological Bureau of China.[13] The SSI questionnaire was filled out immediately after landing. Those subjects who did not have weapon firing or equipment operation tasks within 6 h after sea voyage training were not included ($N = 261$) in the following WLD survey. The remaining 1314 subjects who filled out and returned the WLD questionnaires at 24 h following landing were included in the further statistical analysis ($N = 657$ for both the SSV and RSV subjects).

**Table I.** Seasickness Incidence Questionnaire (SSI).

| QUESTIONS AND EXPLANATIONS | | | | |
|---|---|---|---|---|
| 1. Demographics: Age ___ (years), Height ______ (cm), Weight ______ (kg)<br>This questionnaire is designed to collect the symptoms or discomfort caused by seasickness during the sea voyage training period. | | | | |
| 2. Please mark the real feeling and experience in the corresponding row of transportation type you have traveled on.<br>Multiple choices can be made if you had more than one category of symptom.<br>Please note when you mark the 'no symptom' column, it means that you did not experience seasickness during training and other boxes should not be ticked. | | | | |
| | **Vomiting (emesis or retching** | **Nausea (queasy or nauseated** | **Other Symptoms (headache, dizziness, stomach awareness, salivation, frequent yawning, or drowsiness)** | **No Symptoms or Did Not Feel Sick** |
| War ships | | | | |
| Landing ships | | | | |
| Small vessels | | | | |

War ships at 1300∼3000 tons of displacement; landing ships at 3000∼5000 tons of displacement; and small vessels at less than 1000 tons of displacement.

### Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics 21 software. The overall incidence rate (IR) of WLD was calculated by 100% − IR of no WLD. The general WLD score was analyzed using the Wilcoxon nonparametric test. The IRs of seasickness and its related symptoms as well as the IRs of WLD items were calculated. Pearson's Chi-squared analysis was performed to examine the difference of ratio. The level of significance was set at $P < 0.05$.

## RESULTS

**Table III** shows no significant differences in the demographics between the SSV and the RSV cohort. The percentage distribution ratios of landing ship trainees in the SSV cohort were significantly higher ($\chi^2 = 44.74$, $P < 0.001$), while the percentage distribution ratios of small vessel trainees were lower than those in the RSV cohort ($\chi^2 = 26.69$, $P < 0.001$). In the SSV cohort, the IRs of vomiting, nausea, and other symptoms were significantly higher, while the IR of no symptoms was lower compared with the RSV cohort ($\chi^2$: 12.13–34.12, $P < 0.001$). The IR of vomiting was significantly lower than the IR of nausea and other symptoms in both cohorts ($\chi^2$: 7.85–119.20, $P < 0.001$).

The RSV cohort had lower overall IRs of WLD than the SSV cohort (54.64% vs. 63.78%, $\chi^2 = 11.34$, $P < 0.01$). **Fig. 2A** shows that the general WLD scores were significantly higher in both SSV and RSV subjects trained on warships and landing ships than those trained on small vessels (Z = −9.38 to −5.18, $P < 0.001$). No difference was observed between war ship trainees and landing ship trainees for both SSV and RSV cohorts. For all types of transportation, the RSV WLD score was significantly below that of the corresponding SSV score (Z = −3.95, $P < 0.001$). Among those trained on war ships and landing ships, the RSV subjects also showed lower general WLD scores than the SSV subjects (Z = −3.32 and −11.62, $P < 0.001$). The RSV subjects trained on small vessels showed a nonsignificant

**Table II.** Working Ability and Life Quality Disturbance Questionnaire (WLD).

| EXPLANATION | | | |
|---|---|---|---|
| This questionnaire is designed to inquire about the general impairment of the latest sea voyage training on working ability and life quality as well as the specific impaired items occurred on land within the 24-h time period (in the past) after your latest sea voyage training (tick boxes). | | | |
| For the general working ability and life quality questionnaire, only one choice should be made for the severity items (severe, moderate, slight, or none). Multiple choices can be made in the specific working ability and life quality item questionnaire if you had more than one category of impaired items. | | | |
| Please read the notes below each question and click in the blank box below each item. | | | |
| **General Impairment on Working Ability and Life Quality** | | | |
| **Severe** | **Moderate** | **Slight** | **None** |
| Please select your general feeling on WLD severity. | | | |
| **Specific Impaired Working Ability Items** | | | |
| **Concentration Distraction** | **Physical Fatigue** | **Firing Accuracy Decline** | **Equipment Operation Disturbance** |
| 1. Concentration Distraction means impairment in focusing your mind during reading, writing, or listening to instructions or any other forms of working document. | | | |
| 2. Physical Fatigue means more prone to feel weak during physical training than usual or apparent decline in score of any physical performance compared with normal records. | | | |
| 3. Firing Accuracy Decline means apparent decrease in ring number during gun shooting accuracy training for fixed targets. | | | |
| 4. Equipment Operation Disturbance means apparent slowdown in operating weaponry equipment or driving military vehicles. | | | |
| **Specific Impaired Life Quality Items** | | | |
| **Anorexia** | **Sleep Disorder** | **Spontaneous Locomotion Decrement** | |
| 1. Anorexia means decreased appetite for eating meals in any form (excluding water or beverages). | | | |
| 2. Sleep Disorder means insomnia at night (hard to fall asleep or frequently awakened during the night) and feeling drowsy during daytime. | | | |
| 3. Spontaneous Locomotion Decrement means inactive or unwilling to do things such as sporting, amusement, or social interaction when they are not obligatory. | | | |

**Table III.** Demographics, Distribution of Trainees on Different Transportation Types, and IR of Seasickness in the SSV and RSV Cohorts.

| | SSV COHORT | RSV COHORT |
|---|---|---|
| Sample size | 657 | 657 |
| Age (years) | 22.85 ± 2.92 | 22.54 ± 2.94 |
| Height (cm) | 175.36 ± 4.53 | 175.42 ± 4.58 |
| Weight (kg) | 69.56 ± 6.88 | 69.94 ± 7.04 |
| BMI | 22.55 ± 3.68 | 22.65 ± 3.99 |
| Transportation | | |
| War ship [*N* (%)] | 36 (5.48) | 61 (9.28) |
| Landing ship [*N* (%)] | 329 (50.08)$^{\Delta}$ | 240 (36.53) |
| Small vessel [*N* (%)] | 292 (44.44) $^{\Delta}$ | 356 (54.19) |
| Seasickness [*N* (%)] | | |
| Vomiting [*N* (%)] | 153 (23.29) $^{\Delta}$ | 103 (15.68) |
| Nausea [*N* (%)]$^{\dagger}$ | 304 (46.27)$^{*\Delta}$ | 201 (30.59)* |
| Other symptoms [*N* (%)]$^{\ddagger}$ | 345 (52.51)$^{*\Delta}$ | 244 (37.14)* |
| No symptom [*N* (%)] | 175 (26.64) $^{\Delta}$ | 266 (40.49) |

SSV: single sea voyage; RSV: repeated sea voyage; BMI: body mass index.
*$P < 0.001$ compared with IR of vomiting; $^{\Delta}P < 0.001$ compared with the RSV group.
$^{\dagger}$The data showed overall IR of nausea regardless of the presence of vomiting or not; $^{\ddagger}$the data showed overall IR of other symptoms regardless of the presence of nausea and vomiting.

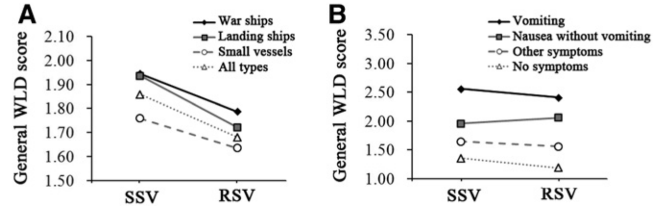


**Fig. 2.** The general WLD score in the SSV and RSV subjects stratified by types of A) transportations or B) seasickness symptoms.

trend of decline in general WLD score compared with the corresponding SSV trainees (Z = −1.89, *P* = 0.058). With respect to the seasickness symptoms, subjects with vomiting or nausea had significantly higher general WLD scores than those with no symptom in both the SSV and RSV cohorts (Z = −12.73 to −8.01, $P < 0.001$). The general WLD scores were also higher in the subjects with vomiting than those with nausea and other symptoms (Z = −5.22 to −3.02, $P < 0.01$ or 0.001). No significant difference was observed between SSV and RSV subjects who had the same type of symptom.

Among working ability items, firing accuracy decline and equipment operation disturbance were less likely to be impacted than concentration distraction and physical fatigue. Among life quality items, anorexia was more likely to be affected than the other two. There was a nonsignificant trend toward lower IRs of concentration distraction and physical fatigue, as well as lower IRs of anorexia, sleep disorder, and spontaneous locomotion decrement in the RSV subjects relative to the SSV ones (**Fig. 3**). With respect to the types of transportation, the IRs of physical fatigue, sleep disorder, and spontaneous locomotion decrement were significantly higher in subjects trained on landing ships than those trained on small vessels for both cohorts ($\chi^2$: 4.54–21.02, $P < 0.05$ or 0.001, **Figs. 4A and B**). The subjects trained on war ships showed a higher IR of sleep disorder and spontaneous locomotion decrement in the RSV and the SSV cohort, respectively, compared with those trained on small vessels ($\chi^2 = 7.71$ and 5.95, $P < 0.05$, Fig. 4B). As for the seasickness symptoms, the subjects with vomiting in both cohorts had significantly higher IRs of concentration distraction, physical fatigue, firing accuracy decline, and equipment operation disturbance as well as higher IR of anorexia and spontaneous locomotion decrement than those with other symptoms and no symptom ($\chi^2$: 6.96–82.26, $P < 0.01$ or 0.001). They also showed higher IRs of concentration distraction and firing accuracy decline ($\chi^2 = 9.17$–11.86, $P < 0.01$) than the nausea subjects, and higher IRs of sleep disorder than the subjects with no symptoms ($\chi^2 = 9.54$ and 12.41, $P < 0.01$, **Figs. 4C and D**). In contrast, subjects with nausea (without vomiting) in both

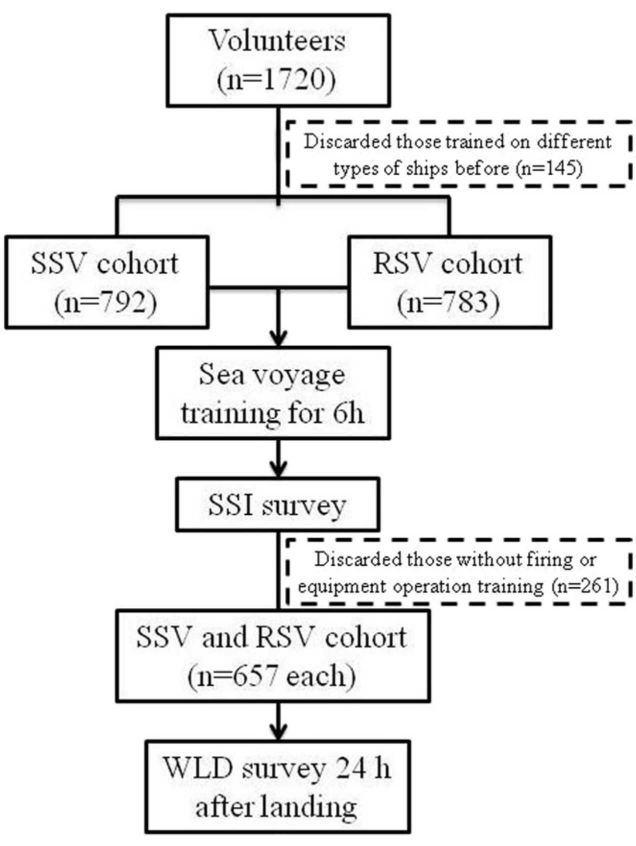


**Fig. 1.** Flowchart of the procedures for the surveys of SSI and WLD in the SSV and RSV subjects.

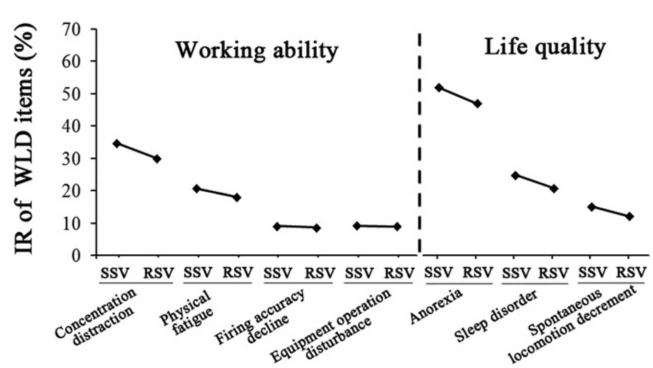


**Fig. 3.** The IRs of specific WLD items in the SSV and the RSV subjects in general.

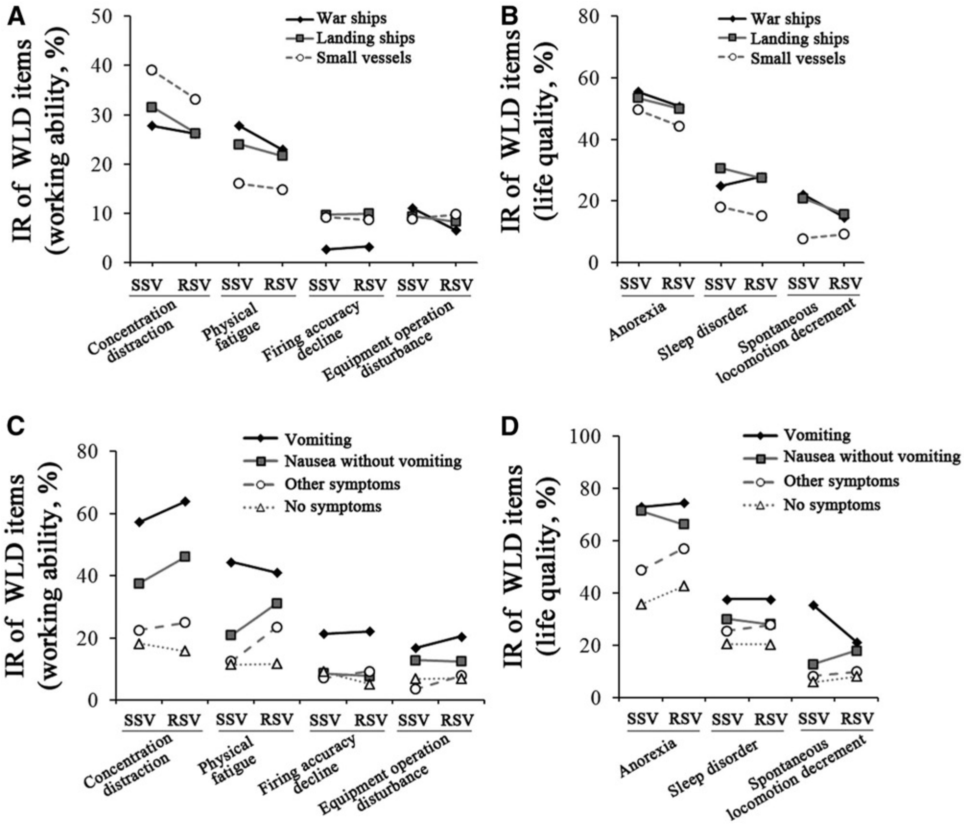


**Fig. 4.** The IRs of specific WLD items in the SSV and the RSV subjects stratified by types of transportations (A and B) or seasickness symptoms (C and D).

cohorts only showed higher IRs of concentration distraction, physical fatigue, and anorexia than those with no symptom, and higher IRs of concentration distraction than those with other symptoms ($\chi^2$: 4.33–39.14, $P < 0.05$, 0.01, or 0.001, Fig. 4C and D).

## DISCUSSION

Previous research has demonstrated that seasickness affects approximately 25–70% of military personnel adversely under moderate to rough sea conditions[17] and leads to about a 40–60% decline in performance efficiency on small and medium vessels.[11] We showed that the IRs of seasickness in SSV and RSV cohorts were about 73% and 60%, respectively, close to the corresponding IRs of WLD at about 64% and 55% after landing. The new findings of the current study were that sea voyage training impaired some aspects of working ability, especially concentration distraction and physical fatigue, and induced a decline in quality of life, especially anorexia and sleep disorder, in Chinese marine corps personnel after landing. Subjects trained on different types of transportations showed differential WLD profiles which were closely related to the seasickness symptoms during the voyage. There was evidence that the repeated exposure to the sea voyage training offered some habituation and reduction in the incidence of seasickness.

Laboratory and field trials have confirmed that the primary etiology of seasickness is the low frequency vertical linear acceleration,[2] which is related to physical fatigue, sleep disorders, decision-making problems, and concentration problems,[30] and could cause a consistent increase in difficulty and decrease in confidence in psychometric test performance as motion sickness symptoms increase.[7] Differences between ships can be attributed to differences in vertical motion frequency.[25] In the present study, we showed that subjects trained on landing ships exhibited more frequent physical fatigue, sleep disorder, and spontaneous locomotion decrements after landing than those trained on small vessels. The subjects trained on war ships also showed a similar tendency. These observations could be attributed to the fact that small vessels differ in vertical motion frequency compared with war ships and landing ships. Although we did not measure the ship motion during training, a series of studies conducted by Lawther and Griffin support our notion that ships with different displacement varied greatly in vertical motion patterns,[25,26] which determine incidence and severity of seasickness.[22] Moreover, it has been reported that motion sickness severity was much higher in subjects exposed to 30 min of motion in a ship's bridge motion simulator under the inside viewing condition than those under an earth-fixed outside viewing condition.[3] The inside viewing condition, as well as adverse environmental factors, such as noise, vibration, and unpleasant smell, on landing ships might lead to more seasickness symptoms than on small vessels. As the configuration of different transportations, such as length-to-beam ratio, height of stacks, and antiroll tank installation can affect seasickness severity and task performance at sea,[14] the structural design of seagoing platforms might also be related to the aftereffects of sea voyage training.

Previous studies showed that passengers and crewmembers might experience a nonvertiginous sense of dizziness called Mal de Debarquement (MdD) immediately after a voyage at sea or following a long flight.[32] MdD, which is described as a sensation of rocking, tilting, or swaying, might be due to oversynchronization of brain networks entrained by a prolonged period of oscillatory passive motion exposure.[4] An early study has reported a high incidence of MdD at 72% in 116 naval crewmembers of seagoing vessels and 66% developed MdD following their first voyage.[19] Another survey in naval crewmembers showed that 73% of 234 subjects had experienced MdD.[20] Our study showed that the overall IR of WLD within 24 h after landing in the SSV cohort (about 64%) was comparable to the incidences of MdD that have been reported previously. It is also noteworthy that the duration of MdD normally ranges from a few minutes to 24 h, mostly within 6 h after landing.[19,20] Given that MdD was strongly related to the severity of seasickness, it might contribute to the occurrence of WLD, especially the tactical training, which was carried out within 6 h after landing.

Vomiting and nausea were associated with self-reported declines in concentration, physical ability, and increased distraction. Vomiting subjects were more prone to report a decline in firing accuracy and equipment operation disturbances within 6 h. These observations were consistent with the result of a previous study which showed that the perceived motion sickness symptoms in a small population from the Swedish amphibious corps during transportation in an amphibious boat took more than 4 h of rest to recover and were correlated to deficits in shooting performance after landing.[9] The current study also found that the impaired military working performance was not associated with nonspecific seasickness symptoms such as drowsiness and lethargy, which could be developed in the absence of vomiting. Repeated training at sea could decrease the WLD score, suggesting that seasickness habituation might alleviate WLD; however, the RSV subjects with vomiting still had remarkably higher WLD scores than other subjects. Based on the fact that the aftereffects of nausea and vomiting could last over 5 d in cancer patients receiving chemotherapy,[16,21] we suggested that the aftereffects of vomiting might be a potential risk factor for severe WLD after landing, especially for the decline in military tactical performance, which might be possibly due to vomiting-induced low morale and dehydration, while the aftereffects of other seasickness symptoms might possibly link to concentration distraction and physical fatigue after landing.

Numerous studies have confirmed that sleep deprivation impairs cognition and motor performance.[24,34,35] It is reasonable to believe that the high IR of sleep disorder might also be related to WLD in subjects with vomiting. Similarly, subjects trained on landing ships showed high IRs of both sleep disorder and physical fatigue as was observed in vomiting subjects. Since military tactical training including shooting and equipment operation was completed prior to receiving an opportunity to sleep, we speculate that physical fatigue could be more possibly attributed to sleep disorder. The relationship between length and quality of sleep and WLD on land after sea voyage training needs to be clarified in further investigations.

In conclusion, sea voyage training for Chinese marine corps personnel can induce a decline in work performance, especially in activities that involve concentration and physical fatigue. The impact will also be evident in the quality of life associated with anorexia and sleep disorder after landing. Transportation types, seasickness severity, and habituation were associated with the sea voyage training induced WLD after landing. The WLD was more evident in the subjects trained on war ships and landing ships than those on small vessels. Seasickness substantially contributed to remarkable WLD after landing, which might be alleviated by repeated exposures. Since seasickness-induced vomiting appeared to be a risk factor for military tactical performance impairment, prevention of seasickness, especially in susceptible individuals, might be a key to promote working performance after landing. The limitation of the present study was that WLD was evaluated by subjective questionnaires. Nevertheless, the consistency of most results in the two cohorts implied the reliability of the protocol used and the conclusions made. As our study only surveyed the occurrence of each WLD item in each subject, but did not observe temporal change patterns during the 24-h period following return to shore, further studies should be performed to clarify the relationship between aftereffects of seasickness and WLD, especially the exact nature and timing of the impact, using objective assessments.

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## REFERENCES

1. Benson AJ, Stott R. Motion sickness. In: Gradwell DP, Rainford DJ, editors. Ernsting's aviation and space medicine, 5th ed. London: CRC Press, Taylor & Francis Group; 2016:781–797.
2. Bos JE, Bles W. Modelling motion sickness and subjective vertical mismatch detailed for vertical motions. Brain Res Bull. 1998; 47(5):537–542.
3. Bos JE, MacKinnon SN, Patterson A. Motion sickness symptoms in a ship motion simulator: effects of inside, outside, and no view. Aviat Space Environ Med. 2005; 76(12):1111–1118.
4. Cha YH. Mal de debarquement syndrome: new insights. Ann N Y Acad Sci. 2015; 1343(1):63–68.
5. Champney RK, Stanney KM, Hash PA, Malone LC, Kennedy RS, Compton DE. Recovery from virtual environment exposure: expected time course of symptoms and potential readaptation strategies. Hum Factors. 2007; 49(3):491–506.
6. Choukèr A, Kaufmann I, Kreth S, Hauer D, Feuerecker M, et al. Motion sickness, stress and the endocannabinoid system. PLoS One. 2010; 5(5):e10752.
7. Coady AL. Effects of moderate motion sickness on estimation of task duration and performance on cognitive tasks. St. John's (Newfoundland): Memorial University of Newfoundland; 2010.
8. Cobb SV. Measurement of postural stability before and after immersion in a virtual environment. Appl Ergon. 1999; 30(1):47–57.
9. Dahlman J, Falkmer T, Forsman F. Perceived motion sickness and effects on performance following naval transportation. J Hum Perf Extrem Environ. 2012; 10(1):3.

10. Dahlman J, Sjors A, Lindstrom J, Ledin T, Falkmer T. Performance and autonomic responses during motion sickness. Hum Factors. 2009; 51(1):56–66.
11. Dobie TG. Motion sickness. Springer series on naval architecture, marine engineering, shipbuilding and shipping. Cham (Switzerland): Springer Cham; 2019.
12. Dziuda L, Biernacki MP, Baran PM, Truszczynski OE. The effects of simulated fog and motion on simulator sickness in a driving simulator and the duration of after-effects. Appl Ergon. 2014; 45(3):406–412.
13. Faltinsen OM. Sea loads on ships and offshore structures. Cambridge (NY): Cambridge University Press; 1990.
14. Fisher MA. The impact of motion and motion sickness on human performance aboard monohull vessels and surface effect ships: a comparative study. Monterey (CA): Naval Postgraduate School; 1982.
15. Geyer DJ, Biggs AT. The persistent issue of simulator sickness in naval aviation training. Aerosp Med Hum Perform. 2018; 89(4):396–405.
16. Glaus A, Knipping C, Morant R, Bohme C, Lebert B, et al. Chemotherapy-induced nausea and vomiting in routine practice: a European perspective. Support Care Cancer. 2004; 12(10):708–715.
17. Golding JF. Motion sickness susceptibility and management at sea. In: MacLachlan M, editor. Maritime psychology. Cham (Switzerland): Springer; 2017:151–183.
18. Golding JF, Kerguelen M. A comparison of the nauseogenic potential of low-frequency vertical versus horizontal linear oscillation. Aviat Space Environ Med. 1992; 63(6):491–497.
19. Gordon CR, Spitzer O, Doweck I, Melamed Y, Shupak A. Clinical features of mal de debarquement: adaptation and habituation to sea conditions. J Vestib Res. 1995; 5(5):363–369.
20. Gordon CR, Spitzer O, Shupak A, Doweck I. Survey of mal de debarquement. BMJ. 1992; 304(6826):544.
21. Hilarius DL, Kloeg PH, van der Wall E, van den Heuvel JJ, Gundy CM, Aaronson NK. Chemotherapy-induced nausea and vomiting in daily clinical practice: a community hospital-based study. Support Care Cancer. 2012; 20(1):107–117.
22. Huppert D, Grill E, Brandt T. Survey of motion sickness susceptibility in children and adolescents aged 3 months to 18 years. J Neurol. 2019; 266(S1, Suppl. 1):65–73.
23. Huppert D, Oldelehr H, Krammling B, Benson J, Brandt T. What the ancient Greeks and Romans knew (and did not know) about seasickness. Neurology. 2016; 86(6):560–565.
24. Kaplan J, Ventura J, Bakshi A, Pierobon A, Lackner JR, DiZio P. The influence of sleep deprivation and oscillating motion on sleepiness, motion sickness, and cognitive and motor performance. Auton Neurosci. 2017; 202:86–96.
25. Lawther A, Griffin MJ. Motion sickness and motion characteristics of vessels at sea. Ergonomics. 1988; 31(10):1373–1394.
26. Lawther A, Griffin MJ. A survey of the occurrence of motion sickness amongst passengers at sea. Aviat Space Environ Med. 1988; 59(5):399–406.
27. Matsangas P, McCauley ME, Becker W. The effect of mild motion sickness and sopite syndrome on multitasking cognitive performance. Hum Factors. 2014; 56(6):1124–1135.
28. Muth ER. The challenge of uncoupled motion: duration of cognitive and physiological aftereffects. Hum Factors. 2009; 51(5):752–761.
29. Oman CM. Are evolutionary hypotheses for motion sickness "just-so" stories? J Vestib Res. 2012; 22(2):117–127.
30. Pisula PJ, Lewis CH, Bridger RS. Vessel motion thresholds for maintaining physical and cognitive performance: a study of naval personnel at sea. Ergonomics. 2012; 55(6):636–649.
31. Reason JT, Brand JJ. Motion sickness. New York: Academic Press; 1975.
32. Tal D, Wiener G, Shupak A. Mal de debarquement, motion sickness and the effect of an artificial horizon. J Vestib Res. 2014; 24(1):17–23.
33. Varlet M, Bardy BG, Chen FC, Alcantara C, Stoffregen TA. Coupling of postural activity with motion of a ship at sea. Exp Brain Res. 2015; 233(5):1607–1616.
34. Whitney P, Hinson JM, Jackson ML, Van Dongen HP. Feedback blunting: total sleep deprivation impairs decision making that requires updating based on feedback. Sleep. 2015; 38(5):745–754.
35. Whitney P, Hinson JM, Nusbaum AT. A dynamic attentional control framework for understanding sleep deprivation effects on cognition. Prog Brain Res. 2019; 246:111–126.
36. Wood CD, Stewart JJ, Wood MJ, Struve FA, Straumanis JJ, et al. Habituation and motion sickness. J Clin Pharmacol. 1994; 34(6):628–634.
37. Wright MS, Bose CL, Stiles AD. The incidence and effects of motion sickness among medical attendants during transport. J Emerg Med. 1995; 13(1):15–20.
38. Zhang LL, Wang JQ, Qi RR, Pan LL, Li M, Cai YL. Motion sickness: current knowledge and recent advance. CNS Neurosci Ther. 2016; 22(1):15–24.