Motion Sickness Incidence During a Round-the-World Yacht Race

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Motion sickness experiences were obtained from participants in a 9 month, round the world yacht race. Race participants completed questionnaires on their motion sickness experience 1 week prior to the start of the race, during the race, and following the race. Yacht headings, sea states, and wind directions were recorded throughout the race. Illness and the occurrence of vomiting were related to the duration at sea and yacht encounter directions relative to the prevailing wind. Individual crewmember characteristics, the use of anti-motion sickness drugs, activity while at sea, and after-effects of yacht motion were also examined with respect to sickness occurrence. Sickness was greatest among females and younger crewmembers, and among crewmembers who used anti-motion sickness drugs. Sickness varied as a function of drug type and activity while at sea. Crewmembers who reported after-effects of yacht motion also reported greater sickness while at sea. The primary determinants of motion sickness were the duration of time spent at sea and yacht encounter direction to the prevailing wind.

RESEARCH HAS ESTABLISHED that seasickness is dependent on the magnitude of ship motion (4,8,10, 12,14). It is generally accepted that low frequency vertical oscillation, typically in the range 0.1 to 0.5 Hz, can be a dominant cause of seasickness (7). Cumulative measures of vertical acceleration may be used to predict vomiting incidence among unacclimatized individuals (11).

The majority of studies of seasickness have involved single voyages (e.g., 8) or multiple, short duration voyages (e.g., 10). There have been few investigations of the incidence of seasickness over prolonged periods at sea. Wiker et al. conducted 3-d sea trials involving different U.S. Coast Guard vessels navigating an octagonal course (16). The incidence of motion sickness was found to be greater on vessels producing greater magnitudes of vertical motion. Vomiting and lesser symptoms of motion sickness were greatest when steaming with a component of head seas.

Applebee et al. (2) reported motion sickness data from a 4-d sea trial involving a 43 m Coast Guard Cutter during the navigation of an octagonal course. The percentage of crew reporting sickness was greatest while sailing into head seas and least in quartering or following seas. Sickness decreased as the number of laps of the octagonal course increased, suggesting that some habituation occurred independent of changes in the sea conditions. Applebee and Baitis (1) reported that the incidence of seasickness varied with heading relative to the sea on a 82 m Coast Guard Cutter.

Goto and Kanda (5) examined sickness data from 35 sea cadets on board a 97-m training vessel during a 4-month voyage in the Pacific Ocean. Motion sickness symptoms decreased logarithmically as days at sea increased, the incidence of motion sickness falling to 10% of its original value over the first 10 d at sea. The authors suggest that motion sickness incidence can be determined from two factors: a human response factor derived from the magnitude of vertical acceleration experienced, and an exposure effect function based on the decline in sickness incidence with days spent at sea.

It is clear that motion sickness during extended periods at sea is not simply determined by the sea conditions. Motion sickness incidence will also be determined by the type of vessel, the vessel heading and the prevailing sea and wind conditions (encounter direction) and the period of time spent at sea. Predictions of seasickness incidence based only on short duration exposures do not allow for the effect of habituation. Initial susceptibility to motion sickness and the rate of habituation may differ from person to person depending on age, gender, previous sailing experience, and the use of anti-motion sickness drugs (e.g., 13).

This study investigated the importance of sea state, vessel encounter direction and continuous exposure duration as determinants of motion sickness over prolonged periods at sea during the 1992–93 British Steel Challenge ocean yacht race. The effects of individual characteristics and individual behavior on the incidence of motion sickness were also examined.

METHODS

The British Steel Challenge: The British Steel Challenge was a 9-month, 28,000 mile yacht race involving a cir-

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cumnavigation of the globe from east to west, against the prevailing winds and currents. The course was divided into four legs: a) from Southampton in England across the Atlantic Ocean to Rio De Janeiro in Brazil; b) around Cape Horn to Hobart in Tasmania; c) across the Indian Ocean to Cape Town in South Africa; d) around Cape of Good Hope and the west coast of Africa to return to Southampton. The mean completion times of the 10 yachts for each leg were 31.4 d (leg 1); 52.1 d (leg 2); 35.4 d (leg 3) and 36.6 d (leg 4). The minimum number of days spent in each port by crewmembers were 12 d (Rio De Janeiro), 28 d (Hobart) and 27 d (Cape Town). The exact duration spent in each port varied for each yacht depending on its completion time for the previous leg. A fleet of 10 identical 67-ft, steel constructed Bermudian Cutters, were built specifically for the Challenge. This allowed each crew of 14 persons to race on even terms without handicap. The yacht with the shortest elapsed time over all four legs was declared the winner. The winning yacht completed the course in 151 d and 12 h.

Race participants: A total of 182 people took part in the British Steel Challenge (24 females, mean age 28.5 yr; 158 males, mean age 38.4 yr). Of the 182 participants, 122 completed all 4 legs of the race; 3 completed 3 legs of the race, 6 completed 2 legs of the race and 51 completed 1 leg of the race. Participants were divided into 10 teams taking their relative ages, strengths and abilities into account. Each team was assigned to a yacht. A professional skipper was also randomly assigned to each team giving a total crew of 14 for each yacht during each leg of the race. With the exception of the 10 skippers who were all highly experienced sailors, the majority of race participants were novice sailors. Before joining the British Steel Challenge, 65% of race participants had little or no previous yachting experience; 26% described themselves as quite experienced and only 9% described themselves as very experienced. All 182 participants completed a 2-yr training program, logging between 3000–5000 nautical miles on a prototype yacht prior to the start of the race.

Motion exposure: The 10 Challenge yachts were fitted with Autohelm digital navigation equipment which gave information on wind direction, heading, speed, and sea depth. For the purposes of the present study, a member of each crew was appointed to keep a record of the predominant wind direction, heading and sea state for each 24-h period of the race as recorded in the yacht's log. The encounter direction of each yacht to the prevailing weather conditions was determined from yacht heading and wind direction.

Motion sickness measurement: Motion sickness questionnaires were administered to race participants at a crew briefing 1 week prior to the start of the race. Information regarding motion sickness occurrence during training, sailing experience prior to the British Steel Challenge and the socio-demographic characteristics of crewmembers were surveyed.

During the race, crewmembers were issued with motion sickness log books. Each log book contained report sheets to be filled in for every 24-h period at sea so as to provide information on sickness occurrence and anti-motion sickness drug usage.

A post-race questionnaire was sent to all race participants following completion of the race, 1 week after the return of the last yacht. The purpose of the questionnaire was to give crewmembers an opportunity to report more extensively on motion sickness occurrence during the race. This questionnaire also allowed motion sickness data to be obtained on individual crewmembers for whom pre-race or in-race assessments were not available.

TABLE I. CREWMEMBER TOTALS AND QUESTIONNAIRE RESPONSE RATES AS A FUNCTION OF YACHT.

Yacht Name	Total Crew	Number of Respondents		
		Pre-race	In-race	Post-race
British Steel II	20	11	2	14
Commercial Union	17	6	4	6
Coopers & Lybrand	21	15	13	11
Group 4	17	7	0	11
Heath Insured	18	12	9	11
Hofbraü Lager	17	13	0	9
Interspray	15	11	3	5
Nuclear Electric	23	11	12	14
Pride of Teeside	17	10	2	11
Rhône Poulenc	17	3	0	7
Total	182	99	45	99

Two measures of motion sickness were calculated from questionnaire responses. An 'illness incidence' was calculated from the number of days on which each crew member had felt ill and the number of days sailing completed on each leg of the race:

$$\text{illness incidence} = \frac{\text{number of days ill}}{\text{number of days sailing}} \times 100$$

'Vomiting incidence' was calculated in a similar manner for each crewmember from the number of days on which vomiting occurred and the number of days sailing.

Response rates: **Table I** shows the number of crewmembers and the questionnaire response rates for each yacht. Response rates to the pre-race and post-race questionnaires were identical (54.5%) but the data were not obtained from the same 99 respondents: 38 crewmembers who did not complete the pre-race questionnaire responded to the post-race questionnaire. Completed in-race logs were obtained from 45 crew pooled across the 10 yachts and the 4 race legs. Data on sea state, heading and wind direction were available for 7 of the 10 yachts. Crewmembers completing the in-race sickness logs were not necessarily the same as those who completed the pre-race and post-race questionnaires. In total, a response was obtained from 140 of the 182 race participants (i.e., 76.9% of the population) for one or more of the motion sickness assessments administered during the study.

No statistically significant effects of sex or age were found between crew members who completed motion sickness assessments and those who did not. No significant differences were found in post-race reports of illness or vomiting between those who completed and those who did not complete sickness logs during the race, or between those who completed and those who did not complete the pre-race motion sickness questionnaire. This suggests that experience of motion sickness did not influence the response rates for the questionnaires.

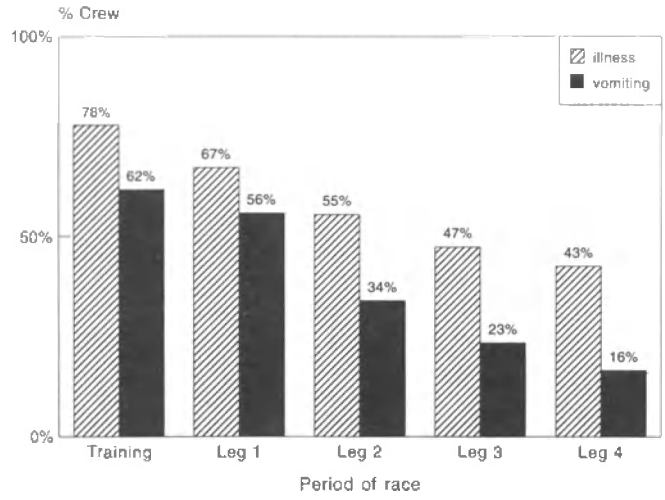

Fig. 1. Percentage of race participants feeling ill or vomiting on one or more occasion during training (pre-race N = 99) and as a function of race leg (post-race N = 99).

TABLE II. DISTRIBUTION OF MOTION SICKNESS SYMPTOMS EXPERIENCED DURING THE BRITISH STEEL CHALLENGE WITH FACTOR ANALYSIS GROUPINGS (POST-RACE ASSESSMENT N = 99).

Factor	% Motion Sickness Variance Explained	Symptoms Included	% Crew Members Experiencing Symptom
1. Principal nausea	45.3%	Retching	34%
		Vomiting	48%
		Nausea	61%
		Pallor	39%
		Heat sensation	56%
		Apathy	47%
2. Head symptoms	10.8%	Fatigue	49%
		Tension	31%
		Headaches	37%
		Dizziness	19%
3. Respiratory	8.4%	Breathing Irregularities	11%
		Increased Salivation	36%
		Sweating	49%
4. Tiredness	7.2%	Yawning	34%
		Drowsiness	33%

RESULTS

Motion Sickness Incidence

Fig. 1 shows the percentage of race participants reporting illness or vomiting during training and during each leg of the race. The data were obtained from the pre-race and post-race questionnaires. Significant decreases occurred in the percentage of crewmembers who reported illness ($\chi^2 = 13.80$; $p < 0.01$; 3 d.f.) and the percentage of crewmembers who reported vomiting ($\chi^2 = 14.64$; $p < 0.01$; 3 d.f.) on successive legs of the race.

During successive legs of the race there was a significant decrease in the number of days on which illness ($\chi^2 = 33.03$; $p < 0.001$; 3 d.f.) or vomiting ($\chi^2 = 26.26$; $p < 0.001$; 3 d.f.) occurred. The average crewmember felt ill on 6.3% of days (mean illness incidence) and vomited on 2.9% of days (mean vomiting incidence) during leg 1. By leg 4 the mean illness incidence had decreased to 2.3% and the mean vomiting incidence had decreased to 0.7% (**Fig. 2**).

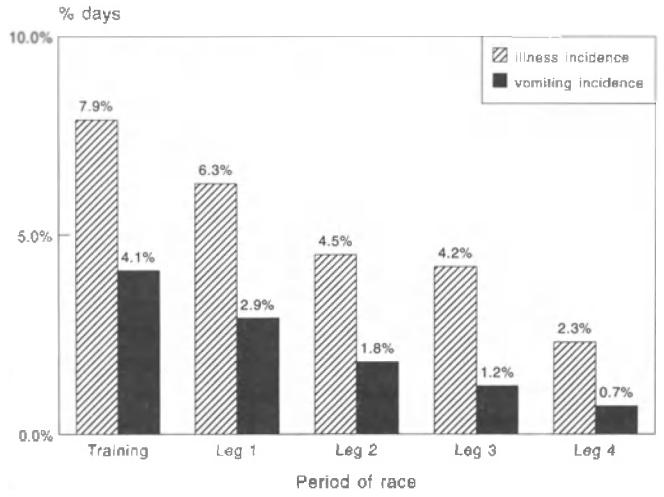

Fig. 2. Mean illness and vomiting incidence during training (pre-race N = 99) and as a function of race leg (post-race N = 99).

Following the race, crewmembers were asked to rate the frequency with which 14 different symptoms were experienced during periods of motion sickness using a 4-point scale: 0, symptom was never experienced; 1, symptom occasionally experienced; 2, symptom often occurred; 3, symptom always occurred. In order of decreasing frequency of occurrence, the symptoms most commonly experienced were nausea, heat sensation, sweating, apathy and fatigue (**Table II**). A factor analysis of symptom frequency data was performed. Four factors were extracted (Table II, Kaiser-Meyer-Olkin measure of sample adequacy = 0.84 suggesting a good factor model). The majority of variance (45.3%) was explained by a principal nausea factor. All 14 symptoms were well related to their associated factors (correlations of ≥ 0.5 existing between each symptom and its parent factor).

Effect of Yacht Motion

Relationships between yacht motion variables and in-race reports of motion sickness were analyzed using combined data from the seven Challenge yachts giving in-race data. This yielded sickness and yacht motion data for 716 d at sea.

Sea state: Positive correlations were found between sea state and illness (Spearman's $\rho = 0.18$; $p = 0.05$) and between sea state and vomiting (Spearman's $\rho = 0.20$; $p < 0.05$). There were no reported cases of illness or vomiting below sea state 2. For sea state ≥ 6, 19.1% of respondents felt ill and 14.3% of respondents vomited (**Fig. 3**).

Duration at sea: Strong negative correlations were found between the consecutive number of days at sea and the percentage of race participants feeling ill (Spearman's $\rho = -0.70$; $p < 0.001$) and the percentage of race participants who vomited (Spearman's $\rho = -0.52$; $p < 0.001$). As time spent at sea increased, the percentage of crew feeling ill and the percentage vomiting decreased

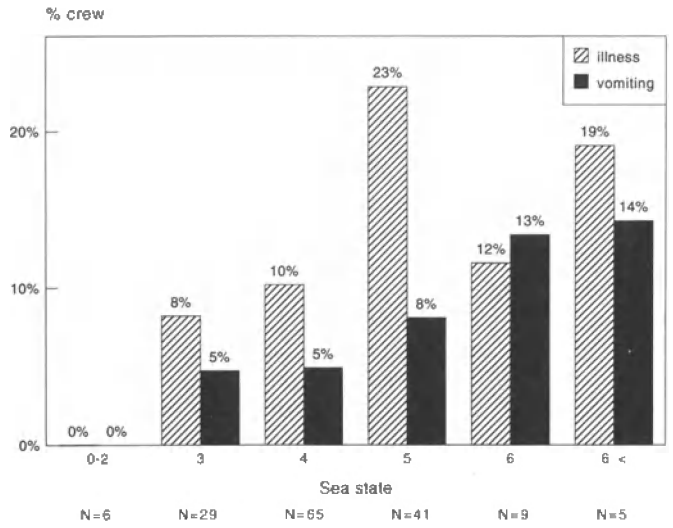

Fig. 3. Percentage of crewmembers experiencing illness and vomiting as a function of sea state. (N = mean number of whole days under each sea state over 4 race legs).

(**Fig. 4**). Approximately 33% of the race participants felt ill and 20% of the race participants vomited during the first 2 d of each leg. Illness and vomiting incidence then fell rapidly with typically less than 5% of the race participants feeling ill or vomiting after 10 d at sea, and only minimal sickness normally occurring after this time. The one exception to this trend was leg 2 of the race (Rio de Janeiro to Hobart) when inclement weather and sea conditions encountered by the fleet in the Southern Ocean (around Antarctica) may have contributed to more prolonged periods of sickness.

Heading, wind and encounter direction: The effects of yacht heading and wind direction were examined by grouping data on eight main compass points (N, NE, E, SE, S, SW, W, NW). The percentage of crewmembers feeling ill was calculated for data falling within ± 22.5° of each compass point. No significant differences were found in crew illness as a function of yacht heading (χ^2 = 5.3; p = 0.51 n.s.; 7 d.f.) or wind direction (χ^2 = 10.92; p = 0.14 n.s.; 7 d.f.). However, crewmember illness tended to be greatest when sailing in southerly or southwesterly directions (e.g., leg 1), and when the prevailing wind blew from the west (e.g., leg 2). Illness levels were lowest when sailing in northerly or northeasterly directions with southerly or southwesterly winds (e.g., leg 4).

Encounter angles in the range 0–180° were calculated for heading and wind direction data over all four race legs:

$$\text{Encounter angle}^\circ = |[|(\text{Heading} - \text{Wind direction})| - 180]|$$

An encounter angle of 0° represents sailing with a following wind (running); an angle of 90° represents sailing with the wind at 90° to either the port or the starboard side of the yacht (reaching); and an angle of 180° represents sailing directly into a head wind (beating).

Positive correlations were found between yacht encounter angles and the percentage of crew feeling ill (Spearman's ρ = 0.21; $p < 0.05$; N = 716) and between yacht encounter angles and the percentage of crew vomiting (Spearman's ρ = 0.24; $p < 0.05$; N = 716), suggesting least sickness when 'running' and greatest sickness when 'beating'. No reported cases of illness occurred in directly following winds or reaching winds up to 15° from the stern and no reported cases of vomiting occurred in reaching winds up to 30° from the stern. The percentage of crewmembers feeling ill was greatest (19.9%) for encounter angles of 120–135°. The percentage of crewmembers vomiting was greatest (11.6%) for encounter angles of 90–105° (**Fig. 5**).

Illness occurrence and vomiting occurrence were also examined as a function of change in encounter angles over time. A change in encounter angle may occur due to variation in wind direction or heading, or both. Changes in encounter angle were calculated by subtracting the yacht encounter angle on each day from that of the previous day. Variation in encounter angle could then be categorized as a change to leeward (with the wind), a change to windward (against the wind) or no change (encounter angle within ± 10° of previous encounter angle). Significantly greater illness (χ^2 = 4.99; p = 0.025) and vomiting (χ^2 = 4.10; p = 0.043) occurred among crewmembers following a change in encounter angle towards windward (16.1% crewmembers ill; 8.0%

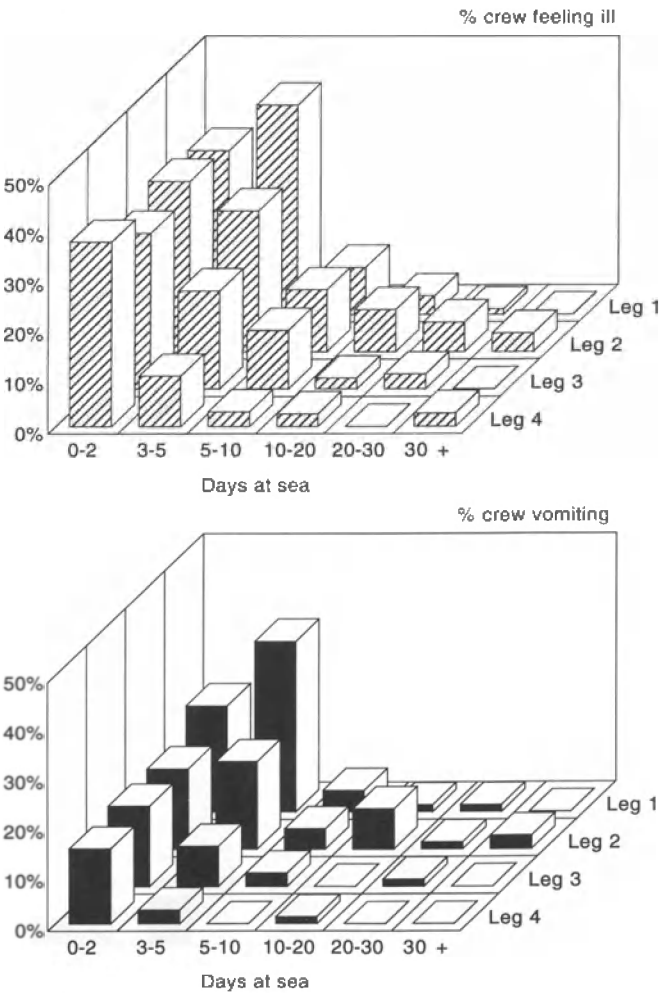

Fig. 4. Illness occurrence and vomiting occurrence as a function of the number of days at sea and the race leg.

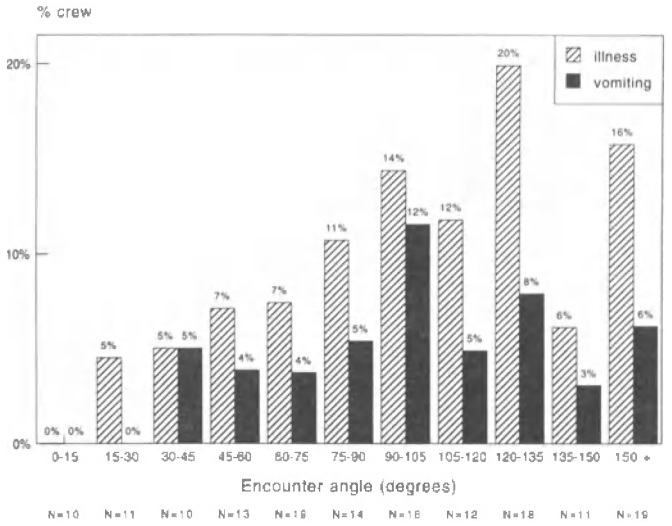

Fig. 5. Percentage of crewmembers feeling ill as a function of yacht encounter angle. (N = mean number of whole days for each encounter angle over 4 race legs).

crewmembers vomiting) compared with no change in encounter angle (8.3% crewmembers ill; 4.3% crewmembers vomiting). No significant differences were observed in illness or vomiting levels between changes in encounter angle to leeward (6.8% crewmembers ill; 3.1% crewmembers vomiting) and unchanging encounter angles.

A model of seasickness: To ascertain the relative importance of different yacht motion variables in the occurrence of motion sickness, stepwise multiple regression analysis was performed. A regression equation containing two yacht motion variables (time spent at sea and encounter angle) was produced. These two variables accounted for 55% of the variance in crew illness (multiple $R = 0.74$), and 31% of the variance in vomiting (multiple $R = 0.56$). The majority of the variance in both illness and vomiting regressions was explained by the duration spent at sea. Forced inclusion of further yacht motion variables into the regression did not significantly increase the multiple regression coefficients for either illness or vomiting.

Effect of Crewmember Variables

The incidence of motion sickness was also examined as a function of the individual and behavioral characteristics of race participants using crewmember responses to post-race sickness assessments (N = 99).

Individual factors: Illness and vomiting incidence were examined as a function of crew gender (**Table III**). During training and over all four race legs, no significant differences were found in illness incidence between males and females ($\chi^2 = 2.76$; $p = 0.09$) although feelings of illness were reported on a greater percentage of days by females (mean = 7.0%) than by males (mean = 3.6%). Females experienced significantly more vomiting than males ($\chi^2 = 4.49$; $p = 0.03$). Averaged over all 4 race legs, females reported vomiting on 2.9% of days while males reported vomiting on only 1.1% of days.

Prior to the race, crewmembers were asked to categorize their previous sailing experience. No significant differences were found in crewmember age ($\chi^2 = 3.05$; $p = 0.38$ ns), the occurrence of illness ($\chi^2 = 0.12$; $p = 0.90$ ns) or vomiting ($\chi^2 = 0.70$; $p = 0.71$ ns) as a function of sailing experience *prior* to the British Steel Challenge. Although illness and vomiting were consistently lower for "very experienced" crewmembers in all four race legs, there was little variation in illness or vomiting between crewmembers classifying themselves as "quite experienced", "a little experienced" or "having no previous experience" of sailing (Table III).

Anti-motion sickness drugs: Approximately half (48.5%) of race participants used anti-motion sickness drugs at some stage of the race. The drug most commonly used by crewmembers was the cinnarazine-based drug *Stugeron* which was used by 30.3% of race participants. Transdermal scopolamine patches were used by 13.1% of race participants and 4.0% used the promethazine-based drug *Avomine*. The remaining 4% of crewmembers used a variety of antihistamine and anticholinergic drugs including dimenhydrinate, oral scopolamine and meclozine. Significant differences occurred in illness incidence as a function of drug usage ($\chi^2 = 9.47$; $p = 0.05$). Crew not taking drugs reported less illness (mean = 2.5% illness days) compared with those taking drugs (mean = 6.4% illness days). Of the drugs used, scopolamine patches were associated with the highest levels of illness (mean

TABLE III. MEAN ILLNESS AND VOMITING INCIDENCE DURING THE RACE AS A FUNCTION OF INDIVIDUAL FACTORS (GENDER, EXPERIENCE, ANTI-MOTION SICKNESS DRUG USAGE AND POST LEG INSTABILITY.

Variable	Group	N	Illness Incidence	Vomiting Incidence
Gender	Male	84	3.6%	1.1%
	Female	15	7.0%	2.9%
Previous sailing experience	No experience	35	4.8%	1.6%
	Little experience	29	4.4%	1.6%
	Quite experienced	26	4.4%	0.9%
	Very experienced	9	0.8%	0.6%
Anti-motion sickness drug used	No drug	48	2.5%	0.5%
	Transdermal scopolamine	13	22.1%	4.1%
	Cinnarazine	30	8.0%	2.3%
	Promethazine	4	4.2%	1.5%
	Oral scopolamine	2	7.0%	3.9%
Post-leg instability occurrence	No	74	3.5%	1.1%
	Yes	25	5.2%	2.0%

TABLE IV. SPEARMAN RANK-ORDER CORRELATION COEFFICIENTS BETWEEN TRAINING AND IN-RACE SICKNESS WITH SELF-RATED MOTION SICKNESS SUSCEPTIBILITY.

Variable	9	8	7	6	5	4	3	2
1. Illness (training)	−0.12	0.51**	0.49**	0.25	0.52**	0.33	0.35*	0.83**
2. Vomiting (training)	−0.05	0.53**	0.57**	0.31	0.50**	0.42*	0.29	—
3. Illness (race)	−0.37*	0.61**	0.54**	0.16	0.37*	0.55**	—	
4. Vomiting (race)	−0.35*	0.61**	0.46**	0.25	0.26	—		
5. General susceptibility	−0.27	0.47**	0.44*	0.51**	—			
6. Child susceptibility	−0.01	0.17	0.23	—				
7. Pre-race susceptibility	−0.42*	0.55**	—					
8. Post-race susceptibility	−0.32	—						
9. Age	—							

* $p < 0.01$; ** $p < 0.001$.
Data from subjects completing pre-race and post-race assessments (N = 61).

= 22.1% illness days) while promethazine was associated with the lowest levels of illness (mean = 4.2% illness days). Similar trends were observed with respect to drug usage and vomiting incidence although the differences did not reach statistical significance ($\chi^2 = 6.8$; $p = 0.15$; Table III).

Post motion effects: The occurrence of post motion instability was reported by 21.4% of crewmembers following leg 1 of the race; 25.3% after leg 2 (the longest leg); 9.3% after leg 3 and 10.8% after leg 4. Crewmembers experiencing instability were found to suffer significantly greater illness ($\chi^2 = 3.84$; $p = 0.05$) and vomiting ($\chi^2 = 4.22$; $p = 0.04$) over all 4 race legs compared with those reporting no instability problems (Table 3). The duration of instability did not reduce significantly following successive race legs ($\chi^2 = 0.6$; $p = 0.89$ ns). In the majority of cases, problems occurred up to 1 d after returning to land, although instability lasting up to 2 d was not uncommon.

Susceptibility: Self-ratings of crewmember motion sickness susceptibility were made using a 5-point scale (1 indicating low susceptibility; 5 indicating high susceptibility). Self-ratings of adult susceptibility to motion sickness made prior to and after the race were the best indicators of in-race sickness, compared to childhood or general susceptibility ratings, or sickness occurrence during training (**Table IV**). Crewmember age correlated negatively with both illness incidence (Spearman's $\rho = -0.37$; $p = 0.001$) and vomiting incidence (Spearman's $\rho = -0.35$; $p = 0.036$) during the race; older race participants suffered less seasickness. Self-rated susceptibilities to motion sickness decreased significantly over time ($\chi^2 = 13.85$; $p = 0.01$). Susceptibility was rated as higher during childhood (mean rating = 2.23) than during adulthood prior to the race (mean rating = 1.97) in agreement with the observed age-related decline in sickness levels. Susceptibility ratings also fell when judged after the British Steel Challenge (mean rating = 1.58) compared to judgements made before the start of the race (mean rating = 1.97), suggesting that participants believed the British Steel Challenge to have reduced their general susceptibility to motion sickness.

Activity: The potential effects of different sailing activities on motion sickness occurrence were examined using 3-point ratings of crewmember opinion. A negative rating indicated an activity was considered to decrease sickness, a positive rating indicated an activity increased sickness, a zero rating suggested the activity had no strong effect. The likelihood of motion sickness varied significantly as a function of sailing activity ($\chi^2 = 238.45$; $p < 0.001$). Cluster analysis revealed three groups of activity variables (**Table V**). Group 1 contained activities likely to increase motion sickness occurrence and included cooking, eating and writing. Group 2 contained activities which were likely to decrease the occurrence of motion sickness and included helming and lying down. Group 3 clustered neutral activities with no strong influence on sickness such as sitting up, sail setting or performing general deck duties. Further factors liable to increase the occurrence of motion sickness were reported by 38.4% of race participants included being below deck or in confined spaces, inhalation of engine fumes, navigational-chart work, dressing/undressing and fear or anxiety. Factors reported as likely to reduce motion sickness were horizon gazing, being above deck and talking.

DISCUSSION

The occurrences of illness and vomiting during the British Steel Challenge were related to the length of time at sea and the characteristics of motion as determined by sea state and encounter angle. Habituation exhibited wide inter-subject variability but most crewmembers were symptom-free after the first 10 d of each leg. Goto and Kanda (5) proposed that the incidence of motion sickness may be derived from the magnitude of vertical

TABLE V. EFFECT OF ACTIVITY ON MOTION SICKNESS SUSCEPTIBILITY WITH CLUSTER ANALYSIS GROUPINGS. (SUBJECTIVE ACTIVITY RATINGS BASED ON POST-RACE ASSESSMENTS N = 99).

Cluster	Activity	Mean Effect Rating
1. Increase motion sickness susceptibility	Cooking	0.85
	Writing	0.55
	Eating	0.30
2. Decrease motion sickness susceptibility	Lying down	−0.78
	Helming	−0.71
3. No effect on motion sickness susceptibility	Sitting up	0.05
	Sail setting	−0.22
	General deck duties	−0.59

boat motion, sickness incidence on the first day of a voyage and duration of time spent at sea.

Motion sickness occurrence has been found to vary with encounter direction to the prevailing weather conditions on British Steel Challenge yachts and on larger vessels (1,2,16). This may be related to changes in the motion as the heading varies. In the present study, sickness was greatest when sailing into head winds (e.g. when sailing against the "Roaring Forties" and the prevailing southern ocean current during leg 2). Least sickness occurred when sailing with a component of following winds (e.g. when sailing with the "South-East Trade Winds" and dominant Benguela Current up the west coast of Africa during leg 4). Due to the nature of the race, the order in which prevailing encounter angles were experienced on each leg could not be controlled and may have influenced the habituation of the crew. However, day to day variations in encounter angles confirmed the same trend, with illness being approximately twice as frequent following a change in encounter angle to windward than for changes to leeward or no change in encounter angle. A model of motion sickness during extended sea travel should therefore incorporate a time-based habituation characteristic and a motion exposure factor which may vary with vessel encounter direction and sea condition.

Some previously reported findings regarding individual susceptibility were confirmed (6,15). The incidence of vomiting was greater for females than males, although it is not known whether this arises due to physiological or anatomical differences between sexes, from activity differences while at sea, from a response bias due a possible reluctance of males to report vomiting episodes, or some other factor. Although age and sickness were not dependent on previous sailing experience, illness and vomiting incidence declined with increasing crewmember age. This suggests that age-related decreases in sickness could not have resulted from differences in prior habituation to yacht motion through previous sailing experience. It is also unlikely that sickness reduced with age due to a self-selection effect, since withdrawals among original Challenge applicants were rare. The observed age-related sickness decline may therefore have resulted from a reduction in sensitivity to motion sickness associated with either biological aging or generalized 'learning' from exposure to motion in various environments.

Sickness was more common for race participants who used anti-motion sickness drugs as opposed to those who did not. It can be assumed that this paradox arises from the increased tendency for those who are most likely to be sick to use anti-motion sickness drugs. No differences in vomiting, but significant differences in illness incidence, occurred as a function of drug type. Illness incidence was highest for users of transdermal scopolamine patches compared with the users of orally taken drugs, suggesting either that transdermal scopolamine was taken by those most susceptible, or that it was less effective, or that it contributed to some aspect of the illness. Side effects reported by transdermal scopolamine users included dry mouths, headaches and blurred vision. Self-ratings of motion sickness susceptibility made before the race were significantly higher for transdermal scopolamine users than for oral drugs users suggesting transdermal scopolamine was used in preference to oral drugs by more severe sickness sufferers. Control over the administration of drugs or more comprehensive consideration of the motion exposure, the consumption of drugs and the initial susceptibility of users is required to ascertain the relative effectiveness of different drugs.

Up to 25% of British Steel Challenge crewmembers experienced instability and balance problems when returning to land. Crewmembers reporting instability following each leg also reported more sickness while at sea. This is consistent with the view that sailors who require longer to habituate to yacht motion at sea (consequently experiencing sickness over a greater number of days) also require longer to rehabituate once back on land.

CONCLUSIONS

On extended sea voyages, the duration of time spent at sea was found to be the critical variable in determining motion sickness occurrence. Changes in vessel encounter direction were also implicated in the occurrence of motion sickness. The selective performance of activities, the use of anti-motion sickness drugs and the individual characteristics of crewmembers were further found to moderate sickness responses.

APPENDIX A

Motion was measured in the fore-and-aft, lateral and vertical directions on one of the ten challenge yachts, *Heath Insured,* during a 5-h training voyage in the Solent in calm sea conditions (sea state 1) 2 weeks prior to the start of the race. Acceleration was measured using three accelerometers secured in the port side amidships cabin. The resultant acceleration power spectra are shown in **Fig. a.** The dominant low frequency acceleration occurred at 0.35 Hz in the fore-and-aft direction, at 0.2 Hz in the lateral direction, and at 0.35 Hz in the vertical direction.

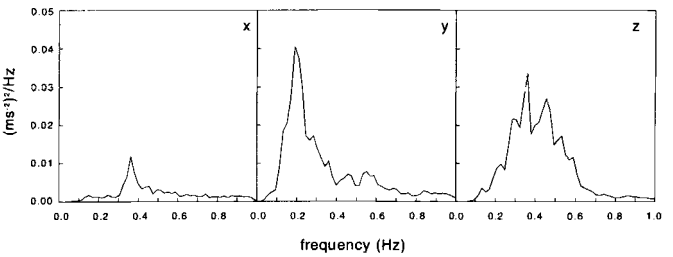

Fig. a. Acceleration power spectra for a 5-h voyage on *Heath Insured* (resolution = 0.02 Hz).

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Our work met with the requirements of the Human Experimentation Safety and Ethics Committee of the University of Southampton. The yacht race was not our responsibility and would have taken place without the conduct of our study. All subjects participated voluntarily in our study and could have withdrawn from the study at any point without prejudice. This was made explicit to all participants at a verbal presentation given immediately prior to the start of the study.

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