Flying after diving: a questionnaire-based evaluation of pre-flight diving behaviour in a recreational diving cohort

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Key words
Altitude; Decompression sickness; Guidelines; Health surveys; Surface interval; Vacation

Abstract
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Introduction: Divers are recommended to observe a pre-flight surface interval (PFSI) ≥ 24 hours before boarding a plane following a diving vacation. Decompression sickness (DCS) symptoms may occur during or post-flight. This study aimed to examine the adherence of PFSI ≥ 24 in vacationing divers, and if any perceived signs and symptoms of DCS during or after flight were experienced.
Methods: An anonymous online survey was publicised through diving exhibitions and social media. Data included diver/diving demographics, PFSI before flight, flight details, and perceived signs and symptoms of DCS during or after flight.
Results: Data from 316 divers were examined (31% female) with the age range 17–75 years (median 49). Divers recorded 4,356 dives in the week preceding the flight, range 1–36 (median 14). Overall, 251/316 (79%) respondents reported a PFSI of ≥ 24 hours. PFSIs of < 12 hours were reported by 6 respondents. Diagnosed and treated DCS developing during, and post flight was reported by 4 divers with PFSIs ≥ 24 hours and by 2 divers with PFSIs < 24 hours. Fifteen divers boarded a plane with perceived symptoms of DCS.
Conclusions: These data suggest that most divers in this study observed the recommendations of a ≥ 24 hour PFSI with safe outcomes.

Introduction

Commercial air travel exposes a passenger to decreased atmospheric pressure, reduced partial pressure of oxygen and reduced air humidity. Passenger aircraft typically fly at 11,000 to 12,000 metres (m) altitude with a cabin pressure maintained at an equivalent maximum altitude of 2,400 m. At 2,400 m the cabin pressure of 565 mmHg is ~25% lower than at sea level (760 mmHg) and alveolar oxygen tension is reduced by 25% leading to a reduction in arterial PO_2 from 100 mmHg (sea level) to approximately 55 mmHg. Relative humidity at cruising altitude is generally 10–15%, compared to 50–60% in the average home.[1] Decreased pressure, relative hypoxia and potential for dehydration experienced during commercial flight are all known risk factors for decompression sickness (DCS).[2] The time between surfacing from a dive and flying – the Pre-Flight Surface Interval (PFSI) – is important for diving safety. The most common recommended PFSI for recreational divers is 24 hours, with most other recommendations falling within a window of 18–48 hours.[3–9]

Divers may board a plane when symptoms of DCS are already evident, and symptoms may occur or be exacerbated during or after a flight. In severe cases in-flight DCS can result in aircraft diversion to expedite recompression.[1,8–12]

Experimental studies investigating safe PFSIs after diving utilised differing controlled environments and thus excluded real life confounding vacation factors such as alcohol, heat and over-exertion, all of which may contribute to the risk of developing DCS.[13–17]

Studies have indicated that 24 hours can be regarded as a safe and effective PFSI for all divers, though there have been possible indications a 24-hour PFSI may not be appropriate for a small number of divers who might be more pre-disposed to bubbling than others.[18,19] With the popularity of overseas dive vacations requiring commercial flights this study sought to explore the compliance of divers to the PFSI of ≥ 24 hours recommendation, and the hypothesis that a PFSI of ≥ 24 hours is sufficient to prevent the development of symptoms of DCS.

Methods

An anonymous online survey was available for completion from June to December 2016 and publicised through the

DDRC Healthcare website and social media platforms, Dive 2016 (22–23 October), UK diving magazines, Divernet, and Deeper Blue websites. All data were anonymous, deduplicated and analysed using descriptive statistics. Approval from a research ethics committee is not required for studies of this type in the UK.

Results

A total of 316 responses (69% male, 31% female) aged from 17–75 years, (median 49, IQR 17) were received from divers who had flown after diving. Individual lifetime dives reported ranged from 8–15,000 (median 450, IQR 922). Dives reported in the last 12 months ranged from 1–500 (median 40, IQR 50) and totalled 17,793 dives. The maximum depth ever dived ranged from 16 to 198 metres of sea water (msw) (median 48, IQR 16).

The number of dives in the week preceding a flight ranged from 1 to 36, (median 14, IQR 11), with the median depths of the last two dives being 25 msw (IQR 10) and 20 msw (IQR 12) respectively. Multi-dive days were reported by 291 (92%) respondents, whilst 25 (8%) respondents reported only diving once a day (single dive days). Consecutive days dived without a break ranged from 2 to 28 (median 6, IQR 1).

PFSIs less than 24 hours (1 x 4 hours, 5 x 8 hours, 13 x 12 hours, 33 x 18 hours) were reported by 52 (16%) respondents, whereas 251 (79%) divers reported PFSI of 24 hours or more, the maximum being 36 hours. No interpretable PFSI data were reported by 13 divers.

Respondents with perceived symptoms consistent with DCS reported limb or joint pain, headache, dizziness or disorientation, visual disturbance, inappropriate weakness/fatigue, difficulty speaking, skin itching, tingling or rash, loss of sensation and/or numbness, problems with thinking, memory or performance, chest pain, and partial paralysis.

Eighteen divers (10 males and eight females) reported onset of symptoms during the flight or post-flight (Figure 1). Details are shown in Table 1 (during flight) and Table 2 (after flight). There was no relationship between divers with or without symptoms and age (Mann-Whitney U test $P = 0.896$), the number of dives in the preceding week (Mann-Whitney U test $P = 0.880$), maximum depth of last dive (Mann-Whitney U test $P = 0.377$), or the surface interval between the last two dives (Mann-Whitney $P = 0.728$). Fourteen divers in this group recorded PFSI ≥ 24 hours (Tables 1 and 2) Additionally, there were no differences in these 18 divers between the sexes with or without symptoms (Fisher's exact $P = 0.200$). Six divers were treated in a hyperbaric chamber with two reporting residual symptoms. None of the 18 divers discussed their symptoms with the aircrew, with five divers not telling anyone about their symptoms at all.

Fifteen divers boarded a plane when already experiencing symptoms of DCS. Neurological symptoms were most frequently reported, with some boarding the plane with more than one symptom. Symptoms were generally exacerbated in flight possibly caused by flight conditions or further evolution of the original disease. In nine of the 15 divers who developed additional symptoms during and/or after the flight, five were treated in a hyperbaric chamber with two reporting mild residual symptoms (Table 3). None of the participants reported symptoms to the flight crew or sought any medical advice.

Discussion

A diving vacation may not only expose a diver to multi-dive, multi-day diving but potentially also a range of other risk

Figure 1

Symptoms reported by 18 respondents either during or after flight who boarded a plane asymptomatically; some respondents reported more than one symptom

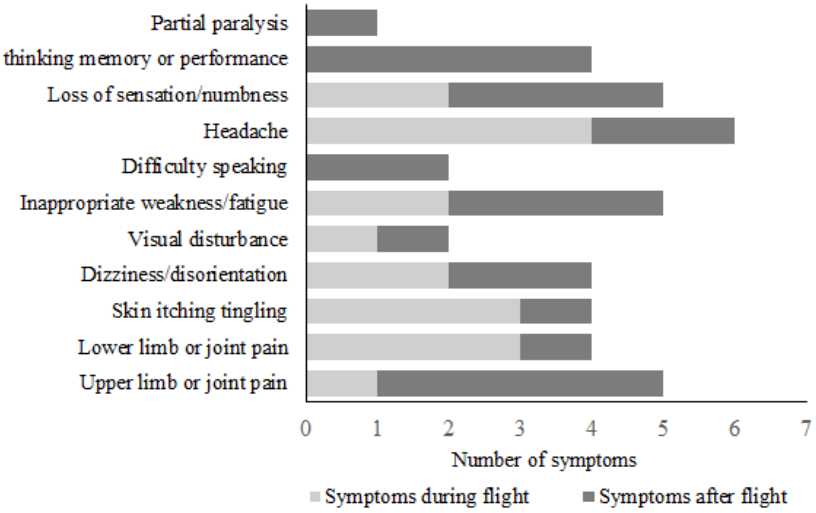

Table 1
Respondents with symptom onset during flight (n = 9); h – hours; min – minutes; PFSI – pre-flight surface interval

Sex, Age (years)	PFSI and flight	Symptoms during flying	Treated in chamber	Symptoms resolved?	Diving demographics Depths are maximum depth of dive
Male, 52	> 24 h. Direct flight 5:30 h	Dizziness and disorientation	Yes	Yes	Twenty dives in the last week, last two dives 18 and 12 msw, each dive 60 min, no stops, open circuit, air
Male, 31	18 h. Direct flight 1 h	Headache, dizziness and disorientation, visual disturbance, inappropriate weakness	Yes	Yes	One single dive to 32 msw for 33 min, 8 min at 5 msw extended safety stop because of 15m·min^{-1} ascent, open circuit, air, cold water dive
Female, 41	> 24 h. Direct flight 5 h	Upper and lower limb or joint pain, skin itching, loss of sensation. Skin rash after the flight	Yes	No, mild residual symptoms, not specified	Twelve dives in the last week, last two dives 30 msw for 28 min, and 13 msw for 47 min, 3 min at 6 msw both dives, open circuit, air
Female, 26	12 h. Direct flight 6 h	Lower limb or joint pain, headache, inappropriate weakness, skin itching. Dizziness or disorientation after the flight	Yes	Yes	Single dive days, 3 dives in the last week, last two dives, 40 msw for 40 min, and 15 msw to 60 min, no deco details, type of equipment used unclear, technical diver
Male, 62	> 24 h. Direct flight 6 h	Headache, during and after the flight	No	Yes	Six consecutive days, 24 dives in last week, last two dives, 23 msw for 60 min, and 17 msw for 58 min, no deco recorded, open circuit, nitrox
Female, 36	> 24 h. Direct flight 13 h	Loss of sensation	No	Yes	Twelve consecutive days, 14 dives in the last week, last two dives, both 25 msw for 75 min, both with 3 min at 5 msw, open circuit, nitrox
Male, 61	> 24 h. Direct flight 5 h	Lower limb or joint pain	No	Yes	6Six consecutive days, 18 dives in the last week, last two dives, 28 msw for 45 min, and 27 msw for 45 min, both with 3 min at 5 msw, open circuit, air
Male, 24	24 h. Direct flight 3:30 h	Skin itching. Skin rash after the flight	No	Yes	Three consecutive days, 6 dives in the last week, last two dives, 22 msw for 30 min, and 30 msw for 18 min, no deco both dives, open circuit, air
Female, 62	> 24 h. Direct flight 4 h	Headache during and after the flight	No	Yes	Six consecutive days, 24 dives in the last week, last two dives, 10 msw for 50 min, and 6 msw for 40 min, open circuit, air

Table 2

Respondents with symptom onset after flight ($n = 9$); h – hours; min – minutes; PFSI – pre-flight surface interval

Sex, Age (years)	PFSI and flight	Symptoms after flying	Treated in chamber	Symptoms resolved?	Diving demographics Depths are maximum depth of dive
Male, 50	> 24 h. Direct flight 6 h	Headache, dizziness or disorientation, visual disturbance, difficulty speaking, loss of sensation, problems thinking, partial paralysis	Yes	No, mild residual symptoms, not specified	Five consecutive days, 13 dives in the last week, last two dives, 83 msw for 9 min, no deco details given, and 40 msw for 45 min with 12 min at 10 msw, open circuit, air
Male, 53	> 24 h. Direct flight 9 h	Upper limb or joint pain	Yes	Yes	Three consecutive days, 12 dives in the last week, last two dives, 28 msw for 40 min, and 12 msw for 30 min, both dives with stop for 3 min at 6 msw, open circuit, nitrox
Female, 51	> 24 h. Flight with changes, 7 h plus	Dizziness or disorientation, inappropriate weakness, difficulty speaking, skin itching,	No	Yes	Seven consecutive days, 21 dives in the last week, last two dives, 28 msw for 59 min, and 23 msw for 55 min, no deco details given, open circuit, nitrox
Female, 43	> 24 h. Direct flight 5 h	Upper limb or joint pain	No	Yes	Ten consecutive days, 21 dives in the last week, no dive details of the last two dives provided, open circuit, air
Male, 40	> 24 h. Direct flight 5 h	Upper limb or joint pain, dizziness or disorientation,	No	Yes	Two consecutive days, 7 dives in last week, last two dives, 32 msw for 60 min with 6 min deco, closed circuit, and 45 msw for 85 min with 15 min deco, open circuit, dive 2 gas 21% and 50% O_2, technical diver
Male, 54	18 h. Flight with changes 17 h	Headache	No	Yes	Ten dives in the last week, last two dives,15 msw for 40 min, and 16 msw for 40 min, stops on both dives 3 min at 6 msw, open circuit, air
Female, 56	18 h. Direct flight 6 h	Upper limb or joint pain, inappropriate weakness, loss of sensation, problems thinking	No	Yes	Six consecutive days, 9 dives in the last week, last dive, 18 msw for 70 min, open circuit, nitrox
Male, 66	> 24 h. 2 flight changes 6:30 h, 7:30 h	Inappropriate weakness or fatigue	No	No, mild residual problems, not specified	Five consecutive days, 11 dives in the last week, last two dives, 20 msw for 58 min, and 12 msw for 75 min, both dives with 3 min at 5 msw, open circuit, air
Female, 62	> 24 h. 4 flight changes, 2:20 h, 3:15 h, 12:30 h, 1 h	Lower limb or joint pain, problems thinking or performance	No	Yes	Seven consecutive days, 23 dives in the last week, last two dives, 14 msw for 63 min, and 28 msw for 70 min, both dives 3 min at 5 msw, open circuit, nitrox

Table 3

Respondents with symptoms before flight and treated for DCS after flight (n = 5); * Mild residual symptoms post treatment, detail not specified; h – hours; min –minutes; PFSI – pre-flight surface interval

Sex, Age (years)	PFSI and flight	Symptoms before flight	Treated in chamber	What were the reasons for your symptoms?	Diving demographics Depths are maximum depth of dive
Male, 55	24 h. Direct flight 4 h	Upper limb pain, continued during flight	Yes	"*A bend, other divers also thought it was a bend*"	Five consecutive days, 12 dives in the last week, last two dives 30 msw for 45 min with deco 9 msw for 10 min and 3 msw for 9 min. 20 msw for 45 min with deco 9 msw for 15 min and 3msw for 11 min, open circuit, air
Female, 49	24 h. Direct flight 4 h	Headache, dizziness, continued during flight	Yes	"*Carbon monoxide poisoning*"	Six consecutive days, 20 dives in the last week, last two dives 24 msw for 60 min, and 15 msw for 45 min, both dives with "*5 msw safety stop*", open circuit, air
Female, 47	24 h. Indirect flight	Headache, dizziness, inappropriate weakness. Loss of sensation during flight, difficulty speaking and thinking after flight	Yes *	"*Buddy, divers, and doctor put the symptoms down to migraine and seasickness*"	Five consecutive days, 17 dives in the last week, last dive 15 msw with no further details, open circuit, air
Male, 51	> 24 h. Indirect flight	Skin rash. Headache during and after flight	Yes	"*Dehydration, which brought on a cerebral bend*"	Three consecutive days, 6 dives in last week, last two dives 27 msw for 46 min, and 23 msw for 50 min, deco both dives "*3 min safety stop*", open circuit, air
Female, 17	> 24 h. Direct flight 3:30 h	Inappropriate weakness, skin rash. Upper limb pain during the flight. Headache, dizziness, and problems thinking after flight	Yes *	"*Fatigue, back pain due to bad posture, nausea due to traveling*"	Fourteen consecutive days, 16 dives in the last week, last two dives 15 msw for 50 min with 5 min at 5 msw safety stop, and 4 msw for 50 min no deco needed, open circuit, nitrox

factors for developing DCS. Studies from which the current guidelines for flying after diving are derived are not always able to account for confounding factors frequently associated with vacation diving.[10–16]

This study reported a range of PFSIs from 4 hours to more than 36 hours, though the majority (79%) of respondents waited ≥ 24 hours before boarding a flight. Despite observing some noticeably short PFSIs most divers did not suffer any symptoms of DCS, whilst interestingly, most divers who reported perceived symptoms had observed a ≥ 24 hour PFSI. Notwithstanding the possibility that not all the symptoms reported might have been diagnosed as DCS, it is worth noting that the divers treated in a chamber and those with residual symptoms had all observed a PFSI of ≥ 24 hours. However, it could be argued that some divers in this group may have extended their PFSI to > 24 hours due to feeling of uncertainty concerning their health. While most of the divers in this study had undertaken multi-dive days and/or consecutive dive days, one respondent reported one single dive to 32 msw, a PFSI of 18 hours, a 15 msw·minute^{-1} ascent, and subsequently developed DCS symptoms during flight and was diagnosed and treated in a chamber on return to the UK.

PFSI guidelines for recreational divers need to be straightforward. Ideally, they need to be compatible with commercially driven elements of a dive vacation. Significantly increasing the recommended PFSI may represent a marginal increase in safety but could reduce the viability of diving vacations if an extended period were to be occupied by observing a long PFSI at the expense of dive frequency and opportunities. Additionally, our study did not request details regarding any "*complete non-diving days*" taken, or not, during the dive vacation that may have impacted any outcome involving DCS. A balance is required, and our data generally support 24 hours being a pragmatic PFSI with a significantly reduced risk of developing DCS after take-off.

An interesting observation was that none of the divers who reported symptoms consulted the flight crew to establish if supplementary oxygen was available. Also recognised in previous studies, is the boarding of planes with symptoms of DCS already developing.[11,12] Data in our study showed pre-existing symptoms were exacerbated by the flight, with increased reports of neurological symptoms post flight. The financial impact of revealing symptoms of DCS before a flight may play a defining role, as may the multitude of well-documented reasons why under-reporting is prevalent for any illness. Some divers may not take out adequate insurance or could be bound by work/employment commitments to return home not appreciating the possible severity of the consequences of failing to seek appropriate medical help.[20]

An additional factor for non-treatment may be a lack of appropriate medical or recompression facilities, with the best option being to fly elsewhere for management. However, this should be done after diving medical consultation.

LIMITATIONS

This study relied on logbook entries and recall, with the recall element being a significant weakness with possible bias, and the logbook detail not always complete in some instances. All anonymous on-line studies have issues with bias and misreporting, coupled with an inability to follow up records of interest. A self-selection bias is also likely with divers in this study responding if they felt they had something of note to report, resulting in 10% of the respondents reporting perceived symptoms of DCS; though not all were diagnosed and treated as such. However, studies of this type are justified in allowing researchers to gather data that may otherwise remain unreported.

Conclusion

The data presented in this study demonstrate that UK sport divers undertake multi-dive, multi-day diving vacations and then board a flight after observing a wide range of PFSIs. Most divers observe a PFSI ≥ 24 hours and safely fly without developing DCS. Some divers fail to adhere to minimum recommended PFSIs and some will board a flight despite experiencing symptoms of DCS. The reasons for this behaviour are likely complex and beyond the scope of this study. A small proportion of those observing a minimum PFSI of 24 hours develop symptoms of DCS which are generally mild and may simply represent slow progression of existing disease or may represent exacerbated effects from the reduced pressure environment in an aircraft. The confounding factors that cause this subgroup to be susceptible to developing DCS remain the subject of conjecture and as such vigilance for symptoms should be exhibited by all commercial airline passengers after scuba diving despite the risk being small if a 24-hour PFSI is observed.

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