

Self-reported vitality and health status are higher in Dutch submariners than in the general population

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Keywords

Long-term health surveillance; Naval medicine; Occupational health; Quality of life; Submarine medicine

Abstract

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Introduction: Living aboard submarines has a potential negative effect on health. Although studies have evaluated specific health hazards and short-term outcomes, long-term health effects have not been investigated in this population.

Methods: Veteran submariners were contacted through the veterans' society and administered a World Health Organisation validated questionnaire (SF-36) assessing their physical, emotional, and social functioning. Scores were compared with those of the general (reference) population and scores in veteran submariners were differentiated by rank, time at sea and time in service. Statistical analyses were performed using the Wilcoxon signed rank and Kruskal-Wallis tests.

Results: Of the 1,025 submariners approached in December 2019, 742 (72.4%) completed and returned the questionnaire before July 2020. All 742 were men, of median age 68 (interquartile range [IQR] 59–76) years (range 34–99 years). Of these subjects, 10.3% were current smokers, 64.4% were former smokers and 23.7% had never smoked. Submariners scored significantly better ($P < 0.001$) than the general population on all eight domains of the SF-36. Except for 'pain' and 'change in health status over the last year', scores for all domains decreased with age. Scores were not significantly affected by smoking status, rank, service, and time at sea.

Conclusions: Dutch veteran submariners have better self-reported vitality and health status than the general Dutch population. Rank, service, and time at sea did not significantly affect scores of Dutch submariners.

Introduction

The military value of sub-maritime warfare, in particular the submarine services, cannot be understated. Because of their stealth and espionage capabilities, along with their substantial firepower, submarines are commonly deployed as part of covert maritime operations. Depending on the size and type of submarine, these vessels can stay submerged for days to months, although specifics are rarely published due to the covert nature of submarine warfare.

Living in a confined area for long periods of time can have negative effects on submariners.^{1–3} Occupational health specialists must balance the thin line between operational military necessity and the possibilities of preventive medicine.^{1,4} Many specific factors have a negative effect on health. For example, recycling the air when submerged reduces air quality, which could contribute to the development of occupational asthma or lung disease. In addition, the restrictions in available space limit the ability to meet the World Health Organization (WHO) criteria

for daily exercise, which could contribute to obesity and cardiovascular disease.⁵ Moreover, disturbances in circadian rhythm can cause diabetes, cardiovascular disease and cancer.⁶ However, surveys in submariners have shown no adverse effects on markers associated with cardiovascular disease while being submerged.⁷ Lastly, the submariner community in the Royal Netherlands Navy seem to believe their long-term health is negatively affected due to their service aboard submarines.

Many studies to date have analysed health hazards in submarines of the Royal Netherlands Navy. Due to the covert nature of submarine warfare, however, these reports are rarely published in peer reviewed scientific literature. Additionally, many of these reports have focused on specific health hazards, most often on their short-term effects,⁸ making it difficult to determine whether sailing on a submarine affects submariners' quality of life, especially in the long term. Moreover, several publicly available studies have evaluated mortality alone and have not included a more modern perspective on health.^{9,10}

A survey assessing the quality of life of veteran submariners may provide greater understanding of the long-term health effects (LTHE) of sailing on a submarine. This study hypothesised that veteran submariners would have a poorer quality of life than members of the general population, with this reduction perhaps due to the perceived health hazards aboard submarines.

Methods

The Medical Ethics Committee affiliated with the Amsterdam University Medical Centre approved the methods used in this study for handling personal details and privacy and concluded that they were in accordance with the guidelines of the Association of Universities in the Netherlands and the Declaration of Helsinki (document reference: W18-337). The study was also approved by the group commander of the Dutch submarine services and the surgeon general of the Netherlands Armed Forces (document reference: DGO120818027).

CONTEXT

The Royal Netherlands Navy has several diesel-powered submarines of the “*Walrus*” class. Submariners are military personnel who are selected and screened for certain qualities, including medical and psychological parameters. These screenings are identical to those of all members of the Netherlands Armed Forces. Individuals who enter the submarine service must undergo additional dive medical screening, similar to military divers and in compliance with ANEP/MNEP-86.¹¹ Personnel deemed medically fit for the submarine service undergo medical assessments every five years, and yearly after age 40 years. Additionally, submariners scheduled to participate in pressurised submarine escape tower (PSET) training undergo a dive medical examination in accordance with the aforementioned standards. Until 2019, only men were allowed to sail in Dutch submarines; currently both sexes are allowed.

DATA COLLECTION

Health status can be assessed by both qualitative (e.g., interviews) and quantitative (e.g., questionnaires) methods. Although a qualitative approach may yield more detailed results, a quantitative approach was adopted to be able to include as many submariners as possible. General health status can be evaluated using many validated questionnaires. In the present study, health status was evaluated using the Dutch translation of the short form 36 health survey (SF-36) questionnaire.^{12–14} The SF-36 assesses many aspects of health status, such as physical, emotional and social functioning, generating a score on eight health domains with multi-item scales (35 items) and an additional single item assessing change in perceived health during the previous year (12 months). Each score varies from 0 (lowest) to 100 (highest), with 50 being the average of the general population

of the United States of America and validated in the general population of the Netherlands. Additionally, several baseline characteristics were recorded, including age, rank, and time at sea with the submarine service, as well as smoking status. It was estimated that it would take between 15 to 20 minutes to complete the questionnaire.

Subjects were approached through the Dutch submarine veterans’ society, with the opportunity to opt-out of the study. Subsequently, a paper questionnaire was sent to each veteran at his or her home address, and the veteran was asked to complete the form and return it by mail to the Royal Netherlands Navy Diving and Submarine Medical Centre. Participation was voluntary, with no consequences for veterans who did not fill out the questionnaires. To emphasize, only Dutch submariners were included in this study, the reference data are based on the aforementioned studies.^{12–14}

DATA ANALYSIS

Returned questionnaires were included in the database if the subject had sailed aboard a Dutch submarine, with no restriction on length of submarine service. Because no data associated with an individual respondent were recorded, any missing data could not be checked. Subjects were divided into three age groups: < 60 years, 60 to 75 years and > 75 years.

All data were entered in a database, allowing calculations of scores on the domains of the SF-36. As the results were not normally distributed, they were compared using the Wilcoxon signed-rank tests and Kruskal-Wallis tests for hypothesis testing. Statistical analyses were performed using SPSS Statistics for Windows software (IBM Corp; Armonk, NY: 2020, version 27.0), with $P < 0.05$ defined as statistically significant.

Results

Questionnaires were sent to 1,025 veteran submariners in December 2019. Eight respondents (0.01%) died during the time between the initial approach through the veterans’ society and distribution of the questionnaires. After July 2020, no further questionnaires were received. A total of 742 questionnaires (72.4%) were returned. All respondents were men, of median (IQR) age 68 (59–76) years (range, 34–99). By rank, 50.1% of respondents were enlisted men or corporals, 19.4% were (chief) petty officers and 28.4% were officers. The majority (48.7%) served in the technical services, 32.7% in the operational services, 10.6% in the logistic service and 1.3% in the weapons division. Of these subjects, 10.3% were current smokers, 23.7% had never smoked and 64.4% were former smokers. Evaluation by age showed that 186 respondents were aged < 60 years, 226 were aged > 75 years and 325 were aged 60 to 74 years.

Table 1

Relevant characteristics of the study subjects; due to missing data, not all numbers or percentages add up to 100%; (C)PO – petty officer or chief petty officer; IQR – interquartile range

Parameters		Total	< 60 years	60–75 years	> 75 years
<i>n</i>		742	186	325	226
Age, median (IQR)		68 (59–76)	55 (51–57)	68 (64–72)	80 (78–83.5)
Rank <i>n</i> (%)	Enlisted/corporal	372 (50.1%)	95 (51.1%)	176 (54.2%)	100 (44.2%)
	(C)PO	144 (19.4%)	36 (19.4%)	63 (19.4%)	44 (19.5%)
	Officer	221 (28.4%)	50 (26.9%)	86 (26.5%)	75 (33.2%)
	Missing data	15 (2.0%)	5 (2.7%)	0 (0%)	7 (3.1%)
Service <i>n</i> (%)	Technical	361 (48.7%)	88 (47.3%)	165 (50.8%)	107 (47.3%)
	Operational	243 (32.7%)	65 (34.9%)	108 (33.2%)	70 (31.0%)
	Logistics	79 (10.6%)	19 (10.2%)	31 (9.5%)	29 (12.8%)
	Weapons	10 (1.3%)	3 (1.6%)	2 (0.6%)	4 (1.8%)
	Missing data	49 (6.6%)	11 (5.9%)	19 (5.8%)	16 (7.1%)
Smoking <i>n</i> (%)	Never	176 (23.7%)	65 (34.9%)	70 (21.5%)	40 (17.7%)
	Discontinued	478 (64.4%)	98 (52.7%)	216 (66.5%)	163 (72.1%)
	Yes	77 (10.3%)	21 (11.3%)	38 (11.7%)	18 (8.0%)
	Missing data	11 (1.5%)	2 (1.1%)	1 (0.3%)	5 (2.2%)

Table 2

SF-36 scores of subjects in the three age groups; the domains marked with an asterisk (*) varied significantly among the three age groups on Kruskal-Wallis tests

Domain	Total	< 60 years	60–75 years	> 75 years
1. Physical performance *	92 (80–100)	90 (75–95)	95 (82.25–100)	85 (65–95)
2. Limitation due to physical complaints *	100 (75–100)	100 (75–100)	100 (100–100)	100 (25–100)
3. Limitations due to emotional complaints *	100 (100–100)	100 (100–100)	100 (100–100)	100 (67–100)
4. Vitality *	75 (65–90)	80 (65–90)	80 (65–90)	75 (60–85)
5. Mental health *	92 (80–96)	92 (80–96)	92 (84–96)	88 (74–96)
6. Social function *	100 (75–100)	100 (75–100)	100 (75–100)	88 (75–100)
7. Pain	90 (78–100)	90 (78–100)	90 (78–100)	90 (68–100)
8. General perception of health *	70 (55–80)	70 (55–80)	70 (55–85)	65 (50–75)
9. Change in health status	50 (50–50)	50 (50–50)	50 (50–50)	50 (50–50)

Table 1 illustrates the baseline characteristics of these subjects.

Analysis of the results of the SF-36 questionnaires showed that the scores for the first eight domains were significantly higher than 50 on Wilcoxon signed rank tests ($P < 0.000$) (Table 2), which means the submariners scored better than the reference population. The score for the last domain (change in health status over the previous year) was significantly lower than 50, indicating the submariners experienced less change in health status than the general population, with a P -value of 0.030. Additionally, except for domains 7 (pain,

$P = 0.251$) and 9 (change in health status during the previous year, $P = 0.074$) scores of all domains varied significantly among age groups on Kruskal-Wallis tests.

Evaluation by rank showed statistically significant differences on domains 2 (limitation due to physical complaints), 6 (social functioning), 7 (pain) and 9 (change in health status) (Table 3). Evaluation by service (or branch as they are known in some navies) showed a statistically significant difference on domain 2 (limitation due to physical complaints), but this effect was not observed when analysing by age groups.

Table 3 SF-36 scores by rank and service / branch; the domains marked with an asterisk (*) varied significantly between ranks on Kruskal–Wallis tests; domains marked with a dagger (†) varied significantly among the different services

Domain	Enlisted (n = 372)	Petty officers (n = 144)	Officers (n = 211)	Technical (n = 361)	Operational (n = 243)	Logistics (n = 79)	Weapons (n = 10)
1. Physical performance	95 (80–100)	90 (75–95)	95 (85–100)	95 (85–100)	95 (80–100)	94 (85–100)	90 (65–100)
2. Limitation due to physical complaints * †	100 (75–100)	100 (50–100)	1000 (100–100)	100 (62.5–100)	100 (75–100)	100 (100–100)	100 (25–100)
3. Limitations due to emotional complaints	100 (100–100)	100 (100–100)	100 (100–100)	100 (100–100)	100 (100–100)	100 (100–100)	100 (100–100)
4. Vitality	75 (65–85)	75 (60–90)	80 (70–90)	85 (75–91.25)	75 (65–85)	75 (65–90)	75 (60–85)
5. Mental health	92 (80–96)	92 (80–96)	92 (84–96)	90 (83–92)	92 (82–96)	92 (84–96)	92 (72–96)
6. Social function *	100 (75–100)	100 (75–100)	100 (88–100)	100 (100–100)	100 (75–100)	100 (75–100)	100 (63–100)
7. Pain *	90 (78–100)	90 (68–100)	100 (78–100)	100 (84.5–100)	90 (69–100)	90 (78–100)	90 (68–100)
8. General perception of health	70 (55–80)	67.5 (55–80)	70 (60–85)	65 (60–77.5)	70 (55–85)	70 (60–80)	65 (50–80)
9. Change in health status *	50 (50–50)	50 (50–50)	50 (50–50)	50 (50–56.25)	50 (50–50)	50 (50–50)	50 (50–50)

Time at sea was longer for enlisted men (median, 96 months; IQR, 56–142 months) than for petty officers (median, 79.5 months; IQR, 48–121.5 months) and officers (median, 42 months; IQR, 26.3–60 months). Evaluation of the relationship between rank/time at sea and scores on the domains of the SF-36 showed that, except for domains 8 (general perception of health), and 9 (change in health status), higher SF-36 scores were significantly associated with lower rank/longer time at sea ($= < 0.05$ by Wilcoxon signed rank tests). For officers, time at sea was significantly associated with scores on all nine domains of the SF-36; for petty officers, time at sea was significantly associated with scores on domains 1, 4, 8, and 9; and for the enlisted men, time at sea was associated with scores on all domains except for domains 3 and 6. SF-36 scores did not differ significantly among the services.

Smoking did not have a statistically significant effect on SF-36 scores, as determined by Wilcoxon signed-rank tests, with *P*-values between 0.166 (physical performance) and 0.914 (change in health status). These findings were observed in all age groups, ranks, services, and times at sea, as determined using Kruskal-Wallis tests.

Discussion

To our knowledge, this is the first study to report the long-term health status of submariners. These individuals scored significantly higher than the general population on all eight domains of the WHO quality of life questionnaire, independent of age, rank, and time at sea. These findings suggest that sailing on a submarine might not have significant negative effects on submariners’ health.

These results may be due to a ‘healthy worker effect’, in that submariners, and military personnel in general, may be healthier than members of the general population due to the higher fitness requirements of the former.¹⁵ Additionally, having medicals once every five years up until 40 and then yearly thereafter may also have a positive impact on the long-term health effects although we cannot predict to what extent this might be true. Individuals who can no longer meet the military requirements, due for example to illness or an accident, are discharged from the armed forces. Although these results are highly applicable to submariners, health hazards that cause a substantial decrease in function may have been masked in this study, i.e., individual cases where exposure could have led to disease, such as asthma or lung cancer after polluted air exposure, have little effect on the group as a whole. However, this is unlikely as the population was not selected based on time at sea.

The SF-36 questionnaire is a self-reported assessment of vitality and health. Although this introduces bias, quality of life may not be analogous to objective markers.^{9,16} Individuals usually compare their quality of life with that of peers in the same age group.¹⁷ Although objective measures show that elderly subjects have more limitations due to

ailments than younger populations, their perceived quality of life may not differ. The advantage of the method utilised in this study was that, in the absence of chronic disease, the perceived quality of life remains generally unchanged with increasing age. Therefore, this method effectively screens for disease and 'normal ageing', without complex data permutations.

Interestingly, scores among submariners were well above average long after these subjects left military service compared to the general population (Table 2). Because a substantial number of respondents were aged > 75 years, it was reasonable to assume that some health hazards, as mentioned earlier the development of occupational asthma, lung disease, obesity, cardiovascular disease, diabetes, or cancer from sailing on a submarine may show a delayed onset, equivalent to mesothelioma resulting from exposure to asbestos.¹⁷ Although rank is often regarded as a surrogate marker for socioeconomic status, the perceived good health among submariners was minimally affected by access to healthcare or other facilities.¹⁸

The present study also evaluated the smoking status of respondents. In the Netherlands, smoking has the greatest negative effect on health, with 19.4% of the total population being cigarette smokers.¹⁹ Almost two-thirds of the submariners surveyed had previously smoked, with an average time from quitting smoking until survey completion being 24.6 years. These individuals can perhaps be regarded as non-smokers, with only 11% of respondents being current cigarette smokers. This difference in cigarette smoking rates between submariners and the general population may further explain the higher score of the former on the study questionnaires. In addition, smoking has been prohibited aboard Dutch submarines since 2004, which may have encouraged submariners to quit smoking.

STRENGTHS AND LIMITATIONS

Submitting these data to peer review and releasing them for publication may encourage an academic discussion on occupational medicine associated with submarines. Increases in health and safety standards aboard submarines, along with increases in their strategic deployment, may help in setting naval health policy for this specific niche population.

The present study had several limitations. First, the study population consisted of male veterans of the submarine service who were affiliated with the veterans' society. Therefore, extrapolation of these results to other populations should be done carefully. Additionally, members of the submariner community are highly active, with many submariners showing lifelong engagement in the veterans' society. This is illustrated by the response rate of the study population to the questionnaire, which was > 70%. Some veteran submariners, however, may not have received the

questionnaire, but there is no indication that inclusion of these subjects would have affected the results of this study. Second, although the response rate was substantially higher than might be expected from questionnaires, data were unavailable for non-responders and for submariners who died. Therefore, mortality associated with working on a submarine would have been undetected, which may have affected the study results. Finally, the control group in this study consisted of the general population, not the veteran military population. Although no data are currently available for the latter group, similar studies are planned with veterans of the naval fleet and marine corps.

Conclusions

Publication of data evaluating the long-term health status of (veteran) submariners may contribute to the scientific advancement of the submarine community. The Dutch veteran submariner community self-reported vitality and health status were significantly higher than those of the general population. Neither rank, a surrogate marker for socioeconomic status, nor service significantly affected these results. The positive relationship between time at sea and perceived health and the evaluation of a population that includes individuals up to a high age indicate that a submarine is a safe working environment, although modern technologies may have introduced new health hazards that were not considered in this survey. Future research could focus on the self-reported vitality and health status of naval fleet personnel or marines to further substantiate the safety of a submarine as a working environment. Similar studies in navies of other countries may validate these findings.

References

- 1 Beardslee LA, Casper ET, Lawson BD. Submarine medicine: an overview of the unique challenges, medical concerns, and gaps. *Undersea Hyperb Med.* 2021;48:263–78. PMID: [34390631](#).
- 2 Chabal S, Welles R, Haran FJ, Markwald R. Effects of sleep and fatigue on teams in a submarine environment. *Undersea Hyperb Med.* 2018;45:257–72. PMID: [30028913](#).
- 3 Nieuwenhuys A, Dora J, Knufinke-Meyfroyt M, Beckers D, Rietjens G, Helmhout P. "20,000 leagues under the sea": sleep, cognitive performance, and self-reported recovery status during a 67-day military submarine mission. *Appl Ergon.* 2021;91:103295. doi: [10.1016/j.apergo.2020.103295](#). PMID: [33130453](#).
- 4 Guo JH, Ma XH, Ma H, Zhang Y, Tian ZQ, Wang X, et al. Circadian misalignment on submarines and other non-24-h environments – from research to application. *Mil Med Res.* 2020;7(1):39. doi: [10.1186/s40779-020-00268-2](#). PMID: [32814592](#). PMCID: [PMC7437048](#).
- 5 Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med.* 2020;54:1451–62. doi: [10.1136/bjsports-2020-102955](#). PMID: [33239350](#). PMCID: [PMC7719906](#).
- 6 Kervezee L, Kosmadopoulos A, Boivin DB. Metabolic and cardiovascular consequences of shift work: the role of

- circadian disruption and sleep disturbances. *Eur J Neurosci.* 2020;51:396–412. doi: [10.1111/ejn.14216](https://doi.org/10.1111/ejn.14216). PMID: [30357975](https://pubmed.ncbi.nlm.nih.gov/30357975/).
- 7 Gunner F, Lindsay M, Brown P, Shaw A, Davey T, Lanham-New S, et al. Impact of the occupational environment of a submerged submarine on cardiometabolic health of Royal Navy submariners. *Occup Environ Med.* 2020;77:368–73. doi: [10.1136/oemed-2019-106292](https://doi.org/10.1136/oemed-2019-106292). PMID: [32179635](https://pubmed.ncbi.nlm.nih.gov/32179635/).
 - 8 Kang J, Song YM. The association between submarine service and multimorbidity: a cross-sectional study of Korean naval personnel. *BMJ Open.* 2017;7(9):e017776. PMID: [28947461](https://pubmed.ncbi.nlm.nih.gov/28947461/). PMID: [32179635](https://pubmed.ncbi.nlm.nih.gov/32179635/).
 - 9 Huber M, Knottnerus JA, Green L, van der Horst H, Jadad AR, Kromhout D, et al. How should we define health? *BMJ.* 2011;343:d4163. doi: [10.1136/bmj.d4163](https://doi.org/10.1136/bmj.d4163). PMID: [21791490](https://pubmed.ncbi.nlm.nih.gov/21791490/).
 - 10 Inskip H, Snee M, Styles L. The mortality of Royal Naval submariners 1960–89. *Occup Environ Med.* 1997;54(3):209–15. doi: [10.1136/oem.54.3.209](https://doi.org/10.1136/oem.54.3.209). PMID: [9155783](https://pubmed.ncbi.nlm.nih.gov/9155783/). PMID: [9155783](https://pubmed.ncbi.nlm.nih.gov/9155783/).
 - 11 North Atlantic Treaty Organization. Technical and medical standards and requirements for submarine survival and escape (ANEP/MNEP-86). Brussels, Belgium; 2014.
 - 12 Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care.* 1992;30:473–83. PMID: [1593914](https://pubmed.ncbi.nlm.nih.gov/1593914/).
 - 13 Aaronson NK, Muller M, Cohen PD, Essink-Bot ML, Fekkes M, Sanderman R, et al. Translation, validation, and norming of the Dutch language version of the SF-36 health survey in community and chronic disease populations. *J Clin Epidemiol.* 1998;51:1055–68. doi: [10.1136/oem.54.3.209](https://doi.org/10.1136/oem.54.3.209). PMID: [9817123](https://pubmed.ncbi.nlm.nih.gov/9817123/).
 - 14 VanderZee KI, Sanderman R, Heyink JW, de Haes H. Psychometric qualities of the RAND 36-Item Health Survey 1.0: a multidimensional measure of general health status. *Int J Behav Med.* 1996;3:104–22. doi: [10.1207/s15327558ijbm0302_2](https://doi.org/10.1207/s15327558ijbm0302_2). PMID: [16250758](https://pubmed.ncbi.nlm.nih.gov/16250758/).
 - 15 McLaughlin R, Nielsen L, Waller M. An evaluation of the effect of military service on mortality: quantifying the healthy soldier effect. *Ann Epidemiol.* 2008;18:928–36. doi: [10.1016/j.annepidem.2008.09.002](https://doi.org/10.1016/j.annepidem.2008.09.002). PMID: [19041592](https://pubmed.ncbi.nlm.nih.gov/19041592/).
 - 16 Hays RD, Morales LS. The RAND-36 measure of health-related quality of life. *Ann Med.* 2001;33:350–7. doi: [10.3109/07853890109002089](https://doi.org/10.3109/07853890109002089). PMID: [11491194](https://pubmed.ncbi.nlm.nih.gov/11491194/).
 - 17 Snow KK, Kosinski M, Gandek B. SF-36 health survey manual and interpretation guide, 2nd edition. Boston: New England Medical Center, the Health Institute; 1997. [cited 2023 Jul 20]. Available from: <https://books.google.nl/books?id=sJ76ngEACAAJ>.
 - 18 Strand LA, Martinsen JI, Koefoed VF, Sommerfelt-Petersen J, Grimsrud TK. Cause-specific mortality and cancer incidence among 28,300 Royal Norwegian Navy servicemen followed for more than 50 years. *Scand J Work Environ Health.* 2011;37:307–15. doi: [10.5271/sjweh.3140](https://doi.org/10.5271/sjweh.3140). PMID: [21206964](https://pubmed.ncbi.nlm.nih.gov/21206964/).
 - 19 Smoking behavior in the Netherlands 2008–2021 [Internet]. 2021. [cited 2023 Jul 20]. Available from: <https://opendata.cbs.nl/#/CBS/nl/>.

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