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Predictors for the development of temporomandibular disorders in scuba divers

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SUMMARY **The aim was to determine predictors for the development of complaints of temporomandibular disorders (TMD) in a large sample of Dutch scuba divers who were free of any TMD complaints before they started diving actively. Five-hundred and thirty-six scuba divers (mean ± SD age = 40·4 ± 11·9 years; 34·1% women) completed a specifically developed questionnaire, either online or on paper. Stepwise forward logistic regression analysis was performed to predict the presence of TMD pain, with several potential risk factors as predictors. Four hundred and eighty-five of the 536 respondents were free of any TMD pain before they started diving actively. In this sample, TMD pain was present in 214 persons (44·1%). Four predictors contributed significantly to the presence of TMD pain, viz., clenching (OR = 2·466), warm water (OR = 1·685), biting on the mouthpiece (OR = 1·598), and the quality rating of the mouthpiece (OR = 0·887, that is, a higher rating means a smaller odds of having TMD pain). TMD pain is a common complaint among scuba divers who were free of such complaints before they started diving actively. Clenching, biting on the mouthpiece, and a low rating of the mouthpiece are predictors for the presence of TMD pain in scuba divers, while diving in cold water serves as a protective factor for TMD pain.**

KEYWORDS: **diving, temporomandibular joint disorders, pain, prevalence, risk, regression analysis**

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Introduction

Over the past decades, there has been a continuous interest in the associations between scuba diving and temporomandibular disorders (TMDs). A PubMed search, using the text words 'diving' and 'temporomandibular', yielded 28 papers, the earliest of which dated from 1969. A more focused search using MeSH terms ['Diving'(Mesh) AND 'Temporomandibular Joint Disorders'(Mesh)] yielded 17 hits, with the oldest one dating from 1977. This illustrates that although the interest has been continuous, it is also relatively limited.

Already in the eighties of the past century, it was reported that almost a quarter of the scuba divers showed disorders of the lower jaw, the teeth, and/or the musculoskeletal structures of the masticatory system (1). The diving mouthpiece was thought to be a compounding factor for already existing TMD problems as experienced during non-diving activities (1, 2). As the underlying mechanism, biting on the mouthpiece in an effort to keep it in its proper position has been proposed (2–7). Consequently, several studies addressed the issue of designing and constructing customised mouthpieces with the underlying thought that this might help reducing the adverse effects of mouthpieces on the masticatory system (3, 8–13). Despite all these technical efforts and advances, however, customised mouthpieces are still

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not commonly used and TMD complaints are still frequently uttered by 24% up to 68% of scuba divers, especially by women (4, 6, 14).

Although factors like pre-existing TMD complaints, a bad fit of the mouthpiece, biting on the mouthpiece, and female gender, amongst others, have all been suggested in the literature as being associated with TMD in scuba divers; most studies so far were done on relatively small samples, varying from about 60 to almost 300 (4, 6). In addition, with the exception of the retrospective pilot study by Koob *et al.* (6), only univariate analyses have been performed on the data, which hampers an unequivocal interpretation of most of the prior research on this topic. Further, in none of the previous works, TMD complaints that were already present before someone started to dive actively were taken into consideration, while this is an important variable when one is interested in risk factors for the development of TMD in association with scuba diving. Hence, the aim of the present study was to determine predictors for the development of TMD complaints in a large sample of Dutch scuba divers who were free of any TMD complaints before they started diving actively.

Materials and methods

Questionnaire development

A specific instrument for the assessment of TMD complaints among scuba divers was developed, using a stepwise approach. First, the owners of several diving centres throughout the Netherlands were approached with a short list of open questions (Table 1), the responses on which were used to compose the specific instrument. Second, two examples of questionnaires aimed at TMD complaints in divers were identified in the literature (2, 6). Third, the intake questionnaire of the Clinic of Orofacial Pain and Dysfunction of the Department or Oral Kinesiology of ACTA was scrutinised for relevant questions (15). From these sources, a pilot version of the specific instrument for the assessment of TMD complaints among scuba divers was composed. The pilot version was then circulated among the co-authors of this paper, viz., a specialist in questionnaire design (M.A.J.E.), a specialist in TMD and oro-facial pain (F.L.), and an experienced, semi-professional scuba diver-dentist (C.J.v.D.), after which a pilot trial was performed among a team of five experienced divers (KeesieDive, Amsterdam, the Netherlands). All pilot questionnaires were returned, along with some valuable suggestions for improvements. Based on this expert input, the final version of the instrument was established (see Appendix for the questions and response options).

Table 1. Open questions directed at the owners of several diving centres in the Netherlands

1. Have you ever heard divers complain about pain and/or sounds in the jaw? If Yes, which complaint(s) (please give an estimate of the frequency per complaint)?
2. Do you provide (starting) divers with advice(s) to prevent jaw complaints? If Yes, which advice(s) (please specify your advice(s) per complaint)?
3. Do you have any idea about the possible cause(s) of such complaints? If Yes, which cause(s) (please specify the possible cause(s) per complaint)?
4. Which types of mouthpieces do you have available in your diving centre? Which types do you sell frequently? Please specify.
5. What is your opinion about commercially available mouthpieces as opposed to custom-made ones?
6. Have you ever had jaw complaints yourself before, during or after diving?

Procedure

During a 4-week period in June and July 2013, data were collected with the specific instrument, using two different approaches. First, an online version of the questionnaire was made available via Facebook.com. A link to the Facebook page was placed on the three major Dutch websites that are frequently visited by scuba divers, viz., 'duiken.mijntijdschrift.net', 'duikeninbeeld.tv', and 'duikforum.nl'. Second, the questionnaire was hand-delivered at conveniently located diving centres and popular scuba diving spots by two of us (M.K. and E.R.V.). Only three times, an approached diver denied participation. The only reason given for non-participation was a lack of time.

Data analyses

Temporomandibular disorders (TMD) pain and TMJ sounds were used as dependent variables. Temporomandibular disorders (TMD) pain was considered

present when a positive answer was given on the questions 'Have you ever had pain in your jaw muscles?' and/or 'Have you ever had pain in your jaw joint?'. TMJ sounds were scored positively when a positive reply was received on the questions 'Do you experience a clicking sound in your jaw joint?' and/or 'Do you experience a scraping sound in your jaw joint?'.

Chi-squared tests were used to determine associations between risk factors and the dependent variables. Odds ratios along with 95% confidence intervals were calculated as effect size. Stepwise (method forward LR) logistic regression analysis was performed to predict the presence of TMD pain and of TMJ sounds, with the risk factors as predictors.

All statistical analyses were conducted using SPSS (IBM SPSS Statistics for Windows, Version 20.0*).

Results

Of the 536 respondents (mean ± SD age = 40·4 ± 11·9 years; 34·1% women), 265 persons (49·4%) reported to have ever had TMD pain in the masticatory muscles and/or in the TMJ. Of the respondents reporting pain in the muscles or in the joints, 24 and 46 persons, respectively, indicated that their pain was already present before they started to dive actively. Nineteen of these 70 individuals reported both muscle pain and joint pain before they started diving. As this study's aim was to assess possible predictors for the development of TMD pain in association with diving, persons with any TMD pain before the active diving phase ($n = 51$) were excluded from further analysis. Hence, 485 respondents were free of TMD pain before they started diving. Of these individuals, 214 persons (44·1%) reported the presence of TMD pain. Jaw-muscle pain (present in 198 respondents) was reported during diving by 69 persons (34·8%), after diving by 75 persons (37·9%), and both during and after diving by 54 persons (27·3%). TMJ pain (present in 104 respondents) was reported during diving by 34 persons (32·7%), after diving by 48 persons (46·2%), and both during and after diving by 22 persons (21·2%).

One-hundred and twenty-two persons of the 536 respondents (22·8%) indicated the presence of clicking and/or scraping joint sounds. 95/122 persons reported only clicking sounds, 4/122 only scraping sounds, and 23/122 reported both types of sounds. Only 12 individuals reported that their joint sounds started after they started diving actively. Unfortunately, this number was too small for further statistical analyses. Hence, the focus below will be on possible predictors for TMD pain only.

As a first step in the analysis, univariate associations were assessed between the dependent variable 'TMD pain' (i.e., masticatory muscle pain and/or TMJ pain) and several risk factors. The outcomes of the chi-squared tests, the odds ratios (ORs, with 95% confidence intervals, CIs), and the distribution of the various risk factors over the dependent variable are shown in Table 2. The odds of having TMD pain are 0·581 times smaller for men than for women, while those odds are 1·748 times larger for those who frequently dive in warm water that for those frequently diving in cold water. Further, self-reports of clenching, biting on the mouthpiece and having ever broken the mouthpiece by biting are all positively associated with TMD pain (ORs = 2·861, 2·123, and 1·572, respectively). Finally, the higher someone rated the mouthpiece, the less TMD pain was reported ($P = 0·003$).

As a second step, logistic regression analysis was performed to predict the presence of TMD pain. Only the risk factors with a marginal significance of $P < 0·10$ (Table 2) were entered as predictors into the model, including the quantitative variable 'rating of the mouthpiece'. The final model was significant ($\chi^2(4) = 47·5$; $P < 0·001$), implying that the (sub)set of predictors can distinguish between those with and without TMD pain. Nagelkerke's R^2 of 13% suggest only a modest association between the predictors and TMD pain, although the model did show adequate fit to the data [Hosmer–Lemeshow $\chi^2(8) = 1·69$; $P = 0·99$]. There were no significant interactions between the risk factors. In total, 64·1% of the respondents were categorised correctly (at a cut-off score of 0·5), using the four predictors that contributed significantly to the prediction, viz., clenching (OR = 2·466), warm water (OR = 1·685), biting on the mouthpiece (OR = 1·598), and the rating of the mouthpiece (OR = 0·887, that is, a higher rating means a smaller odds of having TMD pain). The results are shown in Table 3.

Data were collected from two sources. Of the 485 respondents without any TMD pain before their active diving phase, 385 completed the questionnaire online;

*IBM Corp., Armonk, NY, USA.

Table 2. Distribution of risk factors over the dependent variable 'TMD pain'. For dichotomous and categorical variables, odds ratios (ORs, with 95% confidence intervals, CIs), and *P* values (χ^2 test) are given; for quantitative variables scored on 0–10 numeric rating scales, means (standard deviations, SDs) and *P*-values (*t* tests) are provided

	TMD pain		*P*-value	
Risk factor	No	Yes	OR (95% CI)	χ^2 test
Gender				
Female	75	85		0·005
Male	196	129	0·581 (0·40–0·85)	
Years of experience				
0–1	26	15		0·486
2–4	68	58	1·478 (0·72–3·06)	
5–10	79	72	1·580 (0·78–3·22)	
>10	98	69	1·220 (0·60–2·47)	
Diving frequency				
<20	52	37		0·839
20–40	79	60	1·067 (0·62–1·83)	
41–60	65	50	1·081 (0·62–1·89)	
>60	75	67	1·255 (0·74–2·14)	
Headaches				
No	240	186		0·582
Yes	31	28	1·165 (0·68–2·01)	
Neck pain				
No	239	176		0·064
Yes	32	38	1·613 (0·97–2·68)	
Clenching				
No	211	118		<0·001
Yes	60	96	2·861 (1·93–4·24)	
Grinding				
No	218	157		0·065
Yes	53	57	1·493 (0·98–2·28)	
Professional diver				
No	241	189		0·833
Yes	30	25	1·063 (0·61–1·87)	
Water temperature				
Cold	213	145		0·007
Warm	58	69	1·748 (1·16–2·63)	
Biting on mouthpiece				
No	174	98		<0·001
Yes	97	116	2·123 (1·47–3·06)	
Ever broke mouthpiece				
No	207	144		0·026
Yes	64	70	1·572 (1·05–2·35)	
	Mean (SD)	Mean (SD)		*t* test
Stress in daily life	4·61 (2·56)	4·93 (2·13)		0·142
Stress while diving	1·69 (1·85)	1·96 (1·91)		0·118
Rating of mouthpiece	7·57 (1·76)	7·05 (2·04)		0·003

The response option 'Cold' includes 'ice cold' (n = 6) and 'cold' (n = 352); the response option 'Warm' includes 'warm' (n = 76) and 'tropical' (n = 51).

100 filled in the hand-delivered questionnaire. A statistically significant association was found between the source of the data and the presence of TMD pain [$\chi^2(1) = 7{\cdot}51$; $P < 0{\cdot}006$]. The OR of 0·525 (95% CI = 0·33–0·84) shows that the odds of having TMD pain are smaller in the hand-delivered group than in the online group. To assess the consequences of this possible bias in the analysis of the total group, logistic regression analyses were performed on both subgroups separately. Both analyses yielded significant prediction models. The online model (12% explained variance; 64·7% correctly classified) has three predictors for TMD pain, viz., clenching (OR = 2·433), warm water (OR = 1·764), and biting on the mouthpiece (OR = 1·967). In the hand-delivered model (13% explained variance; 69% correctly classified), two significant predictors remained, viz., clenching (OR = 2·621) and biting on the mouthpiece (OR = 2·651). In neither model, the rating of the mouthpiece was predictive for TMD pain. The mean rating did not differ between both sources ($t(483) = -0{\cdot}81$; $P = 0{\cdot}42$).

Discussion

This study demonstrated that pain in the masticatory muscles and/or the temporomandibular joints is quite common among scuba divers: almost half of them reported complaints of painful temporomandibular disorders (TMDs), while they were free of such complaints before they started diving actively. Regression analyses showed that the association between scuba diving and TMD pain can be predicted by self-reported clenching, biting of the diving mouthpiece, and a low rating of the mouthpiece, while diving in cold water serves as a protective factor. The data also suggest that other factors, not included in this study, are of importance in the development of TMD pain.

A strong methodological aspect of the present study is the large sample size. Using the second largest study sample so far, Koob *et al.* (6). collected questionnaire data from 296 experienced divers. These authors performed an *a priori* sample size calculation, and they concluded that their study sample contained a satisfactory number of respondents. While in the present study no sample size calculation was performed, several statistical textbooks recommend a minimum of 50 cases per predictor as a general rule of thumb, which was achieved in the present study.

Table 3. Results from the logistic regression analysis

Predictor	*B*	SE	Wald	df	*P*-value	OR (95% CI)
Constant	−0·001	0·414	0·000	1	0·998	0·999
Clenching	0·903	0·211	18·23	1	<0·001	2·466 (1·63–3·73)
Water temperature	0·522	0·218	5·736	1	0·017	1·685 (1·10–2·58)
Biting on mouth piece	0·469	0·200	5·483	1	0·019	1·598 (1·08–2·37)
Rating of mouthpiece	−0·120	0·052	5·433	1	0·020	0·887 (0·80–0·98)

B, Beta coefficient; SE, standard error of coefficient; Wald test-statistic; df, degrees of freedom; OR (95% CI), Odds ratio with 95% confidence interval.

In none of the previous works on the possible associations between scuba diving and TMD, the presence of any TMD complaints before the active diving phase was taken into account. This is nevertheless important, because the question whether scuba diving contributes to the development of TMD complaints can only be answered when the respondents whose data are being analysed were free of any TMD problems when they started diving actively. Thus, we had to exclude 51 individuals with prior TMD complaints. Nevertheless, a surprising percentage of 44·1% (214/485) of the remaining respondents reporting TMD pain was found, while in the general population TMD pain is reported by only about 10% (16). This high prevalence figure in the present study is the more surprising, because TMD pain is known to affect females the most (16) while our sample has a male predominance. Taken this epidemiological evidence together, this adds to the suggestion that scuba diving and TMD pain may be causally related, although several methodological issues could have contributed to the observed difference (e.g., different time spans over which questions are being asked). In addition, proof for causality is notoriously hard to establish and requires the fulfilment of multiple criteria (17).

The fact that we have used two approaches for our data collection might be considered a weakness of the current study. The hand-delivered questionnaires represent data of the general population of divers, because everyone was approached as described in the methods. The refusals to participate were negligible in number and occurred only for a reason not related to the topic of this study (viz., no time to participate). Hence, a representative sample responded to the questionnaire. The online group, on the other hand, could be considered less representative, because individuals with TMD complaints are more likely to respond that those without such complaints. Indeed, the odds of having TMD pain were smaller in the hand-delivered group than in the online group. When the regression analysis was performed on both groups separately, the final models differed from each other, albeit only minimally. While diving in warm water was still a predictor for TMD pain in the online group, this factor did not reach statistical significance in the hand-delivered group. On the other hand, in both groups clenching and biting on the mouthpiece predicted the presence of TMD pain significantly, as was also the case in the analysis of both groups combined. These two factors can thus be considered strong predictors for TMD pain in scuba divers.

In the present study, TMD pain was assessed as being present or absent only, while no attempt was made to go further into its characteristics, like intensity and duration. Future studies may focus on these pain characteristics in scuba divers. In addition, as self-report of TMD and its associated conditions is characterised by several disadvantages (e.g., being dependent upon the participants' level of knowledge, memory of events, and interpretation of the wording used), a clinical assessment of the study population is worth considering for future studies, although this usually precludes the inclusion of large numbers of participants. Another possible confounder could have been differences in hardness between the various mouthpieces used by our study group. However, the vast majority of current mouthpieces are made of a relatively stiff silicone material, with negligible differences in hardness between brands. Hence, a confounding effect of mouthpiece materials on the present results is unlikely.

In line with the findings of Koob *et al.* (6), clenching was found to be significantly associated with TMD pain in scuba diving. Like tooth grinding, clenching is a bruxism activity that is mainly of unconscious

nature (18). As extensively reviewed by Manfredini and Lobbezoo (19), self-reported bruxism is positively associated with the occurrence of TMD pain, especially daytime clenching (20). However, several potential confounders are likely playing a disturbing role in this association, especially at the diagnostic level. Nevertheless, as again in the present study, self-reported clenching surfaced as an important predictor for TMD pain, the role of clenching in TMD pain seems an important one. It is interesting to note that the odds of having TMD pain were especially large for clenching, and only to a lesser extent for the other significant predictors (see Table 3). This further stresses the marked importance of clenching for having TMD pain.

Biting on the mouthpiece was also a significant predictor for TMD pain in scuba divers, which confirms the suggestion of several previous works (2–7). In contrast to clenching, biting on the mouthpiece is conscious behaviour that is possibly related to a factor like a poor fit of the mouthpiece. Indeed, a low rating of the mouthpiece was also a significant predictor for TMD pain, suggesting that the previously formulated recommendation of improving the fit of the mouthpiece in an attempt to prevent TMD pain (3, 8–13) seems a valid one. Alternatively, biting on the mouthpiece may be an expression of stress while diving. However, this factor did not contribute significantly to the prediction model. A low rating of the mouthpiece may also be caused by other factors than a poor fit, because the question concerns an overall impression. Now that a low rating was found to be associated with TMD pain, future studies may focus on further unravelling this item.

Previous research has suggested that when tested univariately, cold water would be positively associated with TMD pain (4). As indicated in the review by Zadik and Drucker (14), this might be due to an impairment of the lips' contracting capabilities at low temperatures, thus enforcing an extra effort of the jaw-closing muscles. However, Aldridge and Fenlon (4) are rather cautious in the interpretation of their finding, because they noted that in contrast to their warm water data, the data that they collected from cold water areas mainly came from individuals between 20 and 40 years of age – indeed the age range holding most TMD patients (16). It is therefore not surprising that in the present study, in which multivariate statistical analyses were performed, cold water was found to be a protective factor rather than a risk factor for TMD pain in scuba divers. A possible explanation for this finding could be found in studies on the effects of ice water immersion as a means of accelerating post-exercise recovery in sports (21, 22). Given the growing attention for this technique in sports medicine, we suggest that the effects of water temperature on TMD pain in scuba divers be investigated experimentally in future studies.

In short, TMD pain complaints are reported by 44·1% of scuba divers who were free of such complaints before they started diving actively. Clenching, biting on the mouthpiece and a low rating of the mouthpiece are predictors for the presence of TMD pain in scuba divers, while diving in cold water serves as a protective factor for TMD pain.

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Ethical considerations

The scientific and ethical aspects of the protocol were reviewed and approved by the review board of the Netherlands Institute of Dental Sciences. Informed consent was obtained from all participants.

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Conflicts of interest

No conflicts of interest declared.

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Appendix A.

The final version of the specific instrument for the assessment of TMD complaints among scuba divers: questions (response options)

1 What is your gender? (female/male)
2 What is your age? (years)
3 How many years do you already dive? (0–1/2–4/5–10/>10 years)
4 How many time per year do you dive? (<20/20–40/41–60/>60)
5 On a scale from 0 to 10, how much stress do you experience in your everyday life? (0/---/10)

(0 = no stress/---/10 = a lot of stress)

6 On a scale from 0 to 10, how much stress do you experience while diving? (0/---/10)

(0 = no stress/---/10 = a lot of stress)

7 Have you ever had pain in your jaw muscles? (no/yes)

If Yes, is this pain present... (during diving?/after diving?/both?)
Was this pain already present before you started diving actively? (no/yes)

8 Have you ever had pain in your jaw joints (the hinge of the jaw in front of the ear)? (no/yes)

If Yes, is this pain present... (during diving?/after diving?/both?)
Was this pain already present before you started diving actively? (no/yes)

9 Do you have frequent headaches? (no/yes)

If Yes, is this pain present... (during diving?/after diving?/both?)
Was this pain already present before you started diving actively? (no/yes)

10 Do you have frequent neck pains? (no/yes)

If Yes, is this pain present... (during diving?/after diving?/both?)
Was this pain already present before you started diving actively? (no/yes)

11 Do you clench your teeth? (no/yes)
12 Do you grind your teeth? (no/yes)
13 Is diving your profession? (no/yes)
14 Do you experience a clicking sound in your jaw joint? (no/yes)

If Yes, when did this sound occur for the first time? (before/after starting to dive actively)

15 Do you experience a scraping sound in your jaw joint? (no/yes)

If Yes, when did this sound occur for the first time? (before/after starting to dive actively)

16 In which water temperatures do you mainly dive? (ice cold, cold/warm, tropical)
17 On a scale from 0 to 10, how do you rate your mouthpiece? (0/---/10)

(0 = extremely poor/---/10 = excellent)

18 Do you bite on your mouthpiece while diving? (no/yes)
19 Have you ever broken your mouthpiece by biting? (no/yes)