Impact of ear protection on occurrence of exostosis in surfers: an observational prospective study of 242 ears

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i. TITLE PAGE

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ii. ABSTRACT

PURPOSE: The aim of the study was to investigate the efficacy of ear protection (earplug and surf hood) in preventing the development of external auditory exostosis (EAE) in surfers.

METHODS: We performed a prospective observational study. Volunteer surfers were recruited from June 2016 to October 2017 on the Brittany coast in France. Each participant filled in a questionnaire and underwent otoscopic digitalized photography to establish the degree of external ear obstruction by two different practitioners. The correlation between the percentage of external ear obstruction and the time spent in water with or without protection was evaluated. Risk factors of EAE were assessed.

RESULTS: Two hundred and forty-two ears were analysed. The incidence of EAE was 89.96% with an average rate of obstruction of 37.65%. Risk factors for EAE were male sex ($p = 0.0005$), number of years practicing surf ($p < 0.0001$) and symptoms of ear obstruction ($p = 0.0358$). A significant correlation was found between EAE severity and number of hours spent in water without any protection (earplugs or surf hood) ($p < 0.0001$). No correlation was found between EAE severity and time spent in water with earplugs ($p=0.6711$) but a correlation was identified between obstruction and time spent in water with surf hood ($p=0.0358$).

CONCLUSIONS: Wearing earplugs is an effective way to prevent EAE in surfers unlike surf hood.

iii. KEYWORDS

- Exostosis
- External auditory canal
- Surfers
- Prevention
- Earplugs
- Risk factors

iv. DECLARATION

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Conflicts of interest/Competing interests:

The authors have no conflict of interest to declare for this publication

Data sharing :

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical considerations

The ethics committee of the CHU de Rennes considers that this research project does not contravene medical ethics. This opinion number 20.36 of the local ethics committee was issued unanimously by the members present.

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MAIN TEXT

INTRODUCTION:

External auditory exostoses (EAE) are multiple, usually bilateral and symmetric benign bone outgrowths arise from the tympanic ring of the external auditory canal (EAC). They are histologically characterized by parallel concentric layers of subperiosteal bone that may lead to partial or full occlusion of the external auditory canal. Mostly asymptomatic and discovered incidentally, EAEs can cause chronic cerumen impaction, recurrent otitis externa, and conductive hearing loss. Surgical treatment may be required when medical management fails to control such symptoms.

While the aetiology of exostosis is not fully established, there is widespread agreement about the major role of the environment (cold water, atmospheric temperature and wind exposure) (1–3). Clinical studies have demonstrated that exposure to water, especially colder than 19°C (66° F), leads to the development of exostosis (2,4–8). The prevalence of exostosis is 6.3 per 1000 people in the general population (9). Owing to exposure to cold water, surfers are the most affected by this pathology called "surfer's ear" (4). In 2012, the International Surfing Association (ISA) claimed 35 million surfers worldwide and was expected to increase to 60 million by 2018. Improvements in wetsuit technology now allow surfers to practice in cold water for long durations, which may lead to an increase in the prevalence and severity of EAE.

Earplugs and wetsuit surf hoods are recommended to prevent EAE since they avoid contact between the external ear canal and cold water (8,10,11). Some studies have found a link between a decrease in external auditory canal obstruction and wearing earplugs or a surf hood (5,12,13). In these studies, the authors rated the severity of exostosis from 1 to 3 but did not assign a numerical value to the obstruction and did not evaluate surfing time with and without earplugs (5). Consequently, they failed to show a correlation between the wearing of protection and a decrease in the development of exostosis.

The aim of the present study was to evaluate the efficacy of wearing earplugs or a surf hood in preventing the development of exostosis by correlating the percentage of occlusion and the time spent in water with or without protection.

MATERIAL AND METHOD

The study was approved by [removed for blind peer review] University Hospital ethics committee. Volunteer surfers were recruited from June 2016 to October 2017 on [removed for blind peer review]. The water temperature at the surfing spots was homogeneous. Inclusion criteria were age over 15 years, having surfed for at least one year and surfing at least 15 times per year. Patients with a history of exostosis surgery were excluded. Verbal consent was given by each participant before filling out the questionnaire and having their ears examined.

Otological examinations were performed by the same practitioner with a Storz® endoscope 0° optic (Karl Storz Endoscope®, Tuttlingen, Germany) with a diameter of 4mm and a length of 6 mm, illuminated by a portable cold light source (Storz®). The lens was placed on a Clearscope 2.0® adapter (Clearwater Clinical ®, Ottawa, Canada) allowing the image to be recorded on an LG G2® smartphone (LG Electronics®, Seoul, South Korea). Digitalized images were analysed by two independent practitioners. The degree of external auditory canal stenosis was rated as a percentage of EAC obstruction. If a difference of 10% or less was found between the two assessments, the average of the two values was used. If the difference was greater, images were re-evaluated by the two practitioners.

The questionnaire collected basic demographic data and surfing behaviour, clinical symptoms and use of ear protection. The sensation of obstruction of the external auditory canal was assessed by a Visual Analog Scale (VAS) (VAS=0 if no sensation; VAS=10 if sensation present all the time). Other water activities such as windsurfing, kitesurfing, swimming, diving, kayaking, sailing and wakeboarding were collected.

Data were initially analysed descriptively with means and standard deviations (s.d) for normal distributions or with median and interquartile range when there was a non-normal distribution.

Statistical comparisons were made using Student's test or Wilcoxon's test for quantitative values and Chi-square tests or Fisher's exact test for qualitative values. ANOVA on repeated values was performed to determine the effect on obstruction percentage. Significant values at the level $\alpha=0.20$ on univariate analysis were included in the top-down multivariate analysis. Pearson's correlation was used to determine relationships. Statistical analysis was performed using SAS®, version 9.4 (SAS Institute®, Cary, NC, USA). A two-sided P value <0.05 was considered significant.

RESULTS

Population

One hundred and forty-one volunteers were included and 282 ears were examined. Six surfers with a history of EAE surgery were excluded. Twenty-eight blurred images were not interpretable. The analyses were carried out on 242 ears. Mean age was 29.9 years old. The number of years surfing was 11.9 (± 7.4) with an average at 132.9 (± 83.3) sessions surfed per year. The mean duration of a session was 2.3 hours (± 0.8) in summer and 1.8 hours (± 0.6) in winter. Participants surfed mainly in cold water and they hadn't spent significant time in warmer waters. The number of otalgia episodes was 0.6 (± 1.5) per year, median=0. The VAS feeling of obstruction score was 3.6 (± 2.8).

Protection

Earplugs had been used by 40% of surfers (n=54) for an average of 4 years (+/-3.3) and during 63.5% (± 35.4) of the time spent in the water. A surf hood had been worn by 63.7% (n=86) of them for an average of 8.3 years (± 6.2) and for 24.6% (± 11) of surfing time. There was no statistical difference between earplug users and non-users in terms of demographic and surfing characteristics (Table 1). Among surfers using earplugs, 22 (40.7%) wore them to prevent ear disease and 32 (59.3%) after experiencing ear symptoms like otalgia, a feeling of obstruction, and tinnitus. Information about earplugs had been obtained by word of mouth in 36 surfers (66.6%) and by a physician in 18 (33.4%). Earplugs used were specifically designed for surfing in 64.8% of cases.

Obstruction

EAE was found in 221 ears (89.96%). The percentage of EAC obstruction was 39.2% (± 28.1). Significant risk factors of ear obstruction in multivariate analysis were i) male sex ($p = 0.0352$), ii) number of years practicing surf ($p < 0.0001$) and iii) VAS of feeling of obstruction related to EAE severity ($p = 0.0349$). No significant risk factors were found for surfing in winter ($p=0.56$) or practicing another aquatic activity ($p = 0.98$). A significant correlation (Pearson's coefficient = 0.3037, $p<0.0001$) was found between the percentage of obstruction and the number of hours spent in water without any ear protection (Figure 1). No correlation was found between the percentage of obstruction and time spent in water with earplugs (Pearson's coefficient = 0.02743, $p = 0.6711$) (Figure 2). A significant correlation was found between the percentage of obstruction and the number of hours spent in water with surf hood (Pearson's coefficient = 0.13499, $p = 0.0358$) (Figure 3).

DISCUSSION

Epidemiology of EAE

EAE date back to prehistoric times and is used as a marker of aquatic activity in bioarchaeological studies (3,14). Experimental and epidemiological studies have shown that its development is related to environmental causes, especially exposure to cold water (4–8,12,15). In this study, 89.96% of surfers had evidence of exostosis, which is higher than reported elsewhere (38% to 80%) (4,5,7,8). This difference in prevalence could be due to the number of years of exposure. Several studies have shown that the frequency of EAE increases significantly after 5 years of surfing (4–6,8). The prevalence of EAE after 10 years of surfing ranges from 89% to 92% (5,7). This is similar to our study where participants had surfed for an average of 11.7 years. Surfing was more intense in our studies than in the others with an average of 131 sessions per year and 95% of participants surfing all year round. This difference is likely due to the fact that our volunteers were recruited in surf shops and surf schools outside of school holidays, thus excluding many occasional surfers.

Strengths of the study

In this study we demonstrate the importance of wearing earplugs to prevent EAE. The efficiency of wearing protection to prevent EAE is controversial. While some authors found wearing earplugs beneficial in reducing the frequency or the severity of EAE (5,12,13), others found no effect (16). In these studies, the degree of obstruction was graded from '0' to '3'; where '0' was no visible exostosis, '1' was 0-33% occlusion, '2' was 33–66% occlusion and '3': 66–100% occlusion (5,16,17). Until now, the difficulty in determining the link between wearing ear protection and the development of EAE has been due to the grading system that not allows a correlation curve to be plotted, and to a lack of statistical power (7). Moreover, those studies analysed obstruction only, without looking for a correlation with the number of hours spent in the water with protection. Most surfers surfed for a period of time without protection and thereafter with earplugs or a surf hood, so assessing obstruction without considering the duration of ear protection does not allow any conclusions to be drawn. Our study is the first to calculate the surfing time with and without protection for each surfer in order to establish a correlation curve between these times and the percentage of obstruction. The correlation curve between the percentage of obstruction and the number of hours surfed with earplugs was flat. There was no correlation between the development of EAE and time surfing with earplugs. On the other hand, the relationship between the number of hours surfed without earplugs and obstruction of the EAC was positive, so there was a correlation between surfing time without earplugs and the development of EAE. Therefore, wearing earplugs is efficient to prevent the development of exostosis. Indeed, the obstruction of the external ear canal did not worsen regardless of the number of hours of surfing with earplugs. On the contrary, a

significant positive correlation was found between the percentage of obstruction and time surfing with surf hood, so wearing surf hood is not an effective means of preventing EAE.

Risk factors of EAE

Male surfers had a higher prevalence of EAE than women in our study, thus confirming the male predominance found by other authors (4,5,18,19). Hurst et al suggested that this is due to the greater involvement of men in aquatic activities and found that, after adjusting for exposure, this result was no longer statistically significant (16). According to our multivariate analysis, male sex seemed to be an independent risk factor of developing EAE, regardless of the number of hours spent in the water. Further investigations with a significant number of female surfers are required to draw firmer conclusions about this issue.

The link between the number of years spent surfing and the severity of EAE is well known (4,6–8). Attlamyr et al showed that each year of exposure to cold water increases the risk of developing EAE by 12% (6). They found that the number of years surfing significantly increased the risk of canal stenosis. Like Chaplin and Stewart, we did not find any significant association between the development of EAE and the number of sessions per year or the number of hours surfing per session (7).

Surfing all year round is a known risk factor of developing EAE compared to surfing only during summer (5,7,13). In our study this factor was not a significant contributor in the multivariate model. The development of exostosis is promoted by water under 19 degrees (2). In Brittany, the water is particularly cold, varying from 8.5 to 17 degrees depending on the time of year (20). The water temperature never exceeds 19 degrees, which may explain the lack of excess risk of developing exostosis in people surfing during the winter in multivariate analysis.

EAE and symptoms

The link between severity of EAE and symptoms has already been reported (5,7). In the present study, surfers with a feeling of ear obstruction had a higher risk of having canal obstruction. This observation should encourage surfers to consult an otolaryngologist as soon as symptoms appear. Otalgia was not related with severity of obstruction, but surfers had an average of 0.6 episodes of otalgia per year and most never had one (median=0). Otalgia is thus not a reliable criterion to predict the development of exostosis.

Applicability of findings

While the wearing of earplugs was shown to be efficient, there is still a lack of awareness about prevention. Surfers started to wear earplugs after the first symptoms appeared. Morris and al

demonstrated that knowledge of EAE was significantly associated with earplug use when surfing (21). Awareness of the need for prevention should be raised in order to reduce the incidence of EAE. The questionnaire revealed that prevention was largely a matter of word of mouth and was not promoted by a physician or an otolaryngologist. It would be beneficial to raise awareness of this disease among general practitioners, particularly those living near the coast, to encourage them to inform their surfing patients about this issue. Furthermore, specialized magazines and surf instructors could also disseminate such information.

CONCLUSION

EAE develops in surfers' ears. Risk factors related to external ear canal obstruction are male sex, number of years practicing surf and feeling of obstructed ear, which were related to EAE severity. Earplugs are effective for preventing obstruction unlike surf hood.

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FIGURE LEGENDS

Table 1: Population using earplugs or not

For qualitative parameters: number of surfers and percentage (%), $\chi 2$ (K) or Fisher (F) test were used.

For quantitative parameters: mean ± standard deviation (Q1; median; Q3). Student test (S) was used.

Figure 1: Correlation between percentage of obstruction of external auditory canal and number of hours spent in water without earplugs or surf hood

Figure 2: Correlation between percentage of obstruction of external auditory canal and number of hours spent in water with earplugs

Figure 3: Correlation between percentage of obstruction of external auditory canal and number of hours spent in water with surf hood.

Figure 2

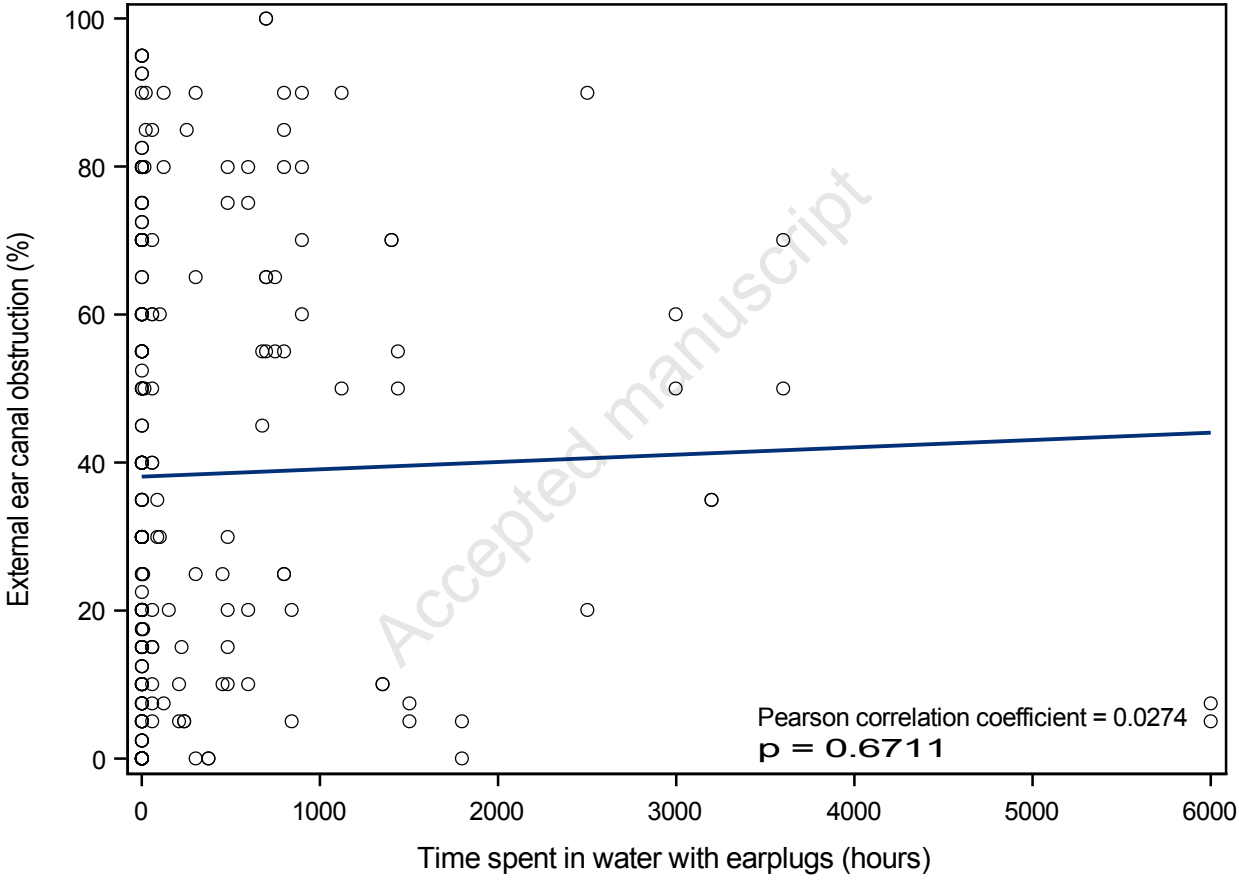

Figure 3

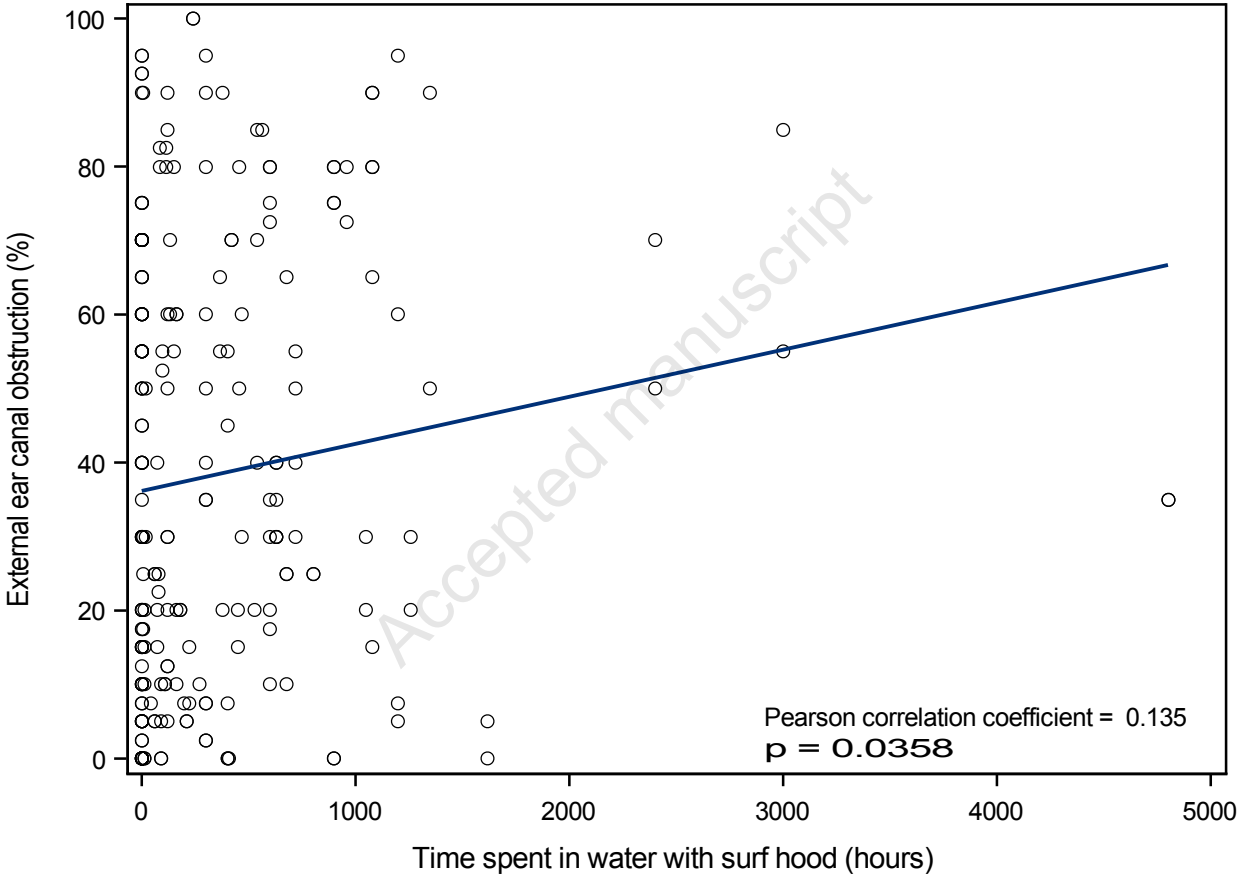

Figure 1

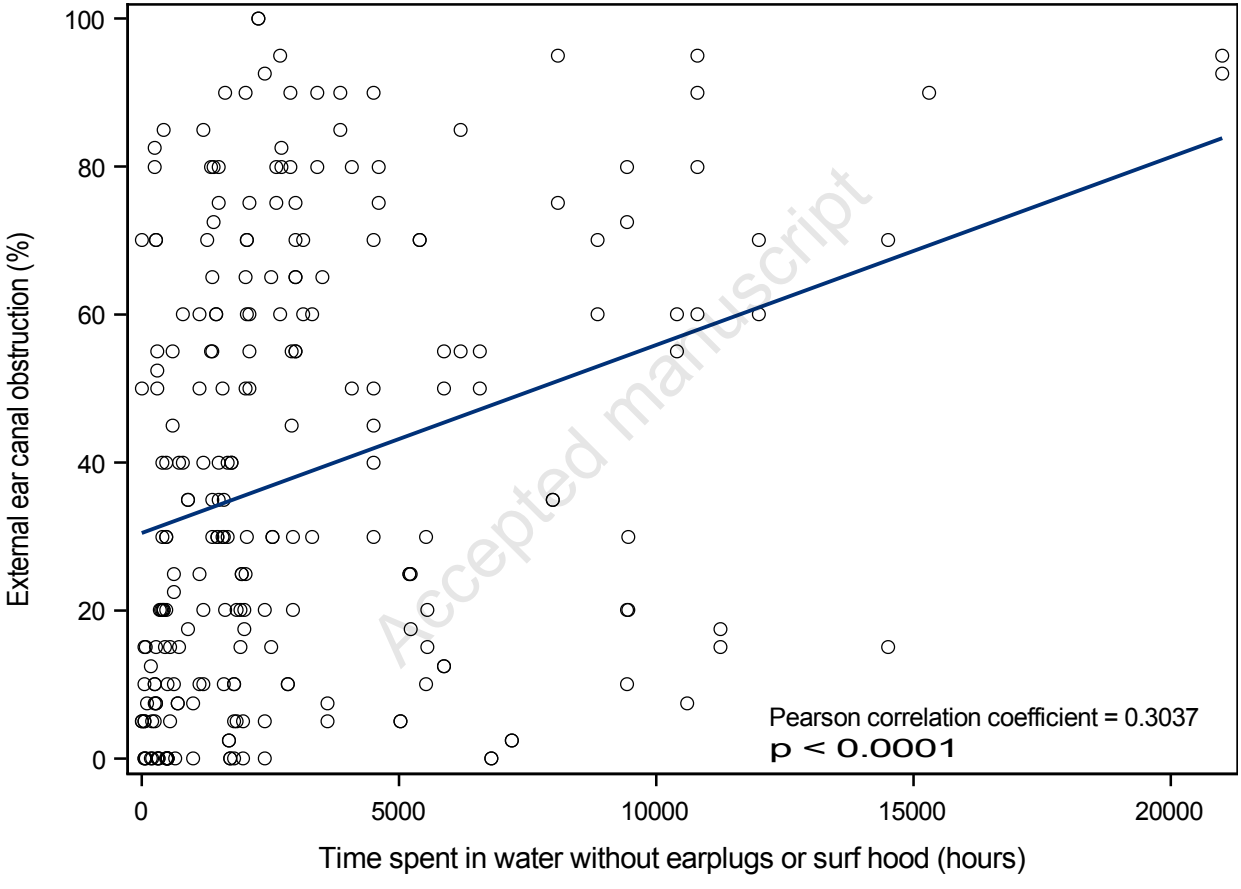
External ear canal obstruction (%)
100
80
60
40
20
0
0
5000
10000
15000
20000
Time spent in water without earplugs or surf hood (hours)
Pearson correlation coefficient = 0.3037
p < 0.0001
Accepted manuscript

Table 1

Variable	Total	Earplugs wearing	No earplugs wearing	*P value*
Sex				*0.2555 (K)*
Male	117 (86.7%)	49 (90.7%)	68 (84.0%)	
Female	18 (13.3%)	5 (9.3%)	13 (16.0%)	
Age	29.9 ± 8.3	31.4 ± 8.6	28.9 ± 7.9	*0.0920 (S)*
	(24.0; 29.0; 35.0)	(25.0; 31.0; 37.0)	(22.0; 28.0; 34.0)	
Otalgia (per year)	0.5 ± 1.5	0.8 ± 1.8	0.4 ± 1.3	*0.0943 (S)*
	(0.0; 0.0; 0.0)	(0.0; 0.0; 1.0)	(0.0; 0.0; 0.0)	
VAS of the obstruction feeling	3.6 ± 2.8	4.1 ± 3.0	3.2 ± 2.7	*0.0526 (S)*
	(1.0; 3.0; 6.0)	(1.0; 4.0; 6.0)	(1.0; 2.5; 5.0)	
Number of years of surfing	11.9 ± 7.4	13.1 ± 6.6	11.1 ± 7.9	*0.1233 (S)*
	(5.5; 10.0; 17.0)	(8.0; 13.0; 18.0)	(5.0; 8.5; 15.0)	
Number of sessions per year	132.9 ± 83.3	136.8 ± 83.2	130.3 ± 83.8	*0.6586 (S)*
	(50.0; 100.0; 180.0)	(170.0; 112.5; 180.0)	(50.0; 100.0; 180.0)	
Number of hours per summer session	2.3 ± 0.8	2.3 ± 0.6	2.3 ± 0.9	*0.6369 (S)*
	(2.0; 2.0; 2.8)	(2.0; 2.0; 3.0)	(2.0; 2.0; 2.5)	
Number of hours per winter session	1.8 ± 0.5	1.9 ± 0.4	1.7 ± 0.6	*0.2248 (S)*
	(1.5; 2.0; 2.0)	(1.5; 2.0; 2.0)	(1.5; 2.0; 2.0)	
Surfing season				
Summer	5 (3.7%)	0 (0.0%)	5 (6.2%)	*0.1569 (F)*
Summer and winter	130 (96.3%)	54 (100.0%)	76 (93.8%)	
Other aquatic activity				
No	83 (61.5%)	34 (63.0%)	49 (60.5%)	*0.7727 (K)*
Yes	52 (38.5%)	20 (37.0%)	32 (39.5%)	
Hood wearing				
No	86 (63.7%)	39 (72.2%)	47 (58.0%)	*0.0928 (K)*
Yes	49 (36.3%)	15 (27.8%)	34 (42.0%)	
Post-session ear care				
No	88 (65.2%)	35 (64.8%)	53 (65.4%)	*0.4656 (F)*
Water rinsing	41 (30.4%)	15 (27.8%)	26 (32.1%)	
Instillation (oil)	1 (0.7%)	1 (1.9%)	0 (0.0%)	
Use of cotton swab	5 (3.7%)	3 (5.6%)	2 (2.5%)	

Table 1: Population using earplugs or not.

For qualitative parameters: number of surfers and percentage (%), $\chi 2$ (K) or Fisher (F) test were used.

For quantitative parameters: mean ± standard deviation (Q1; median; Q3). Student test (S) was used.

Percentage of obstruction	Effectif	Mean ± sd	P value
Sex			
Male	214	41.30 ± 1.94	***< 0.0001***
Female	35	15.36 ± 4.80	
Surfing season			
Summer	12	2.50 ± 8.29	***< 0.0001***
Summer + Winter	237	39.43 ± 1.86	
Earplugs wearing			
Yes	97	42.09 ± 3.00	*0.0607*
No	152	34.82 ± 2.40	
Hood wearing			
Yes	156	39.73 ± 2.37	*0.1547*
No	93	34.17 ± 3.08	
Other water activity			
Yes	154	37.29 ± 2.40	*0.8076*
No	95	38.24 ± 3.06	

Table 2: Risk factors for external auditory canal obstruction