Aalto University

OPEN ACCESS

This is an electronic reprint of the original article.
This reprint may differ from the original in pagination and typographic detail.

Manninen, Iida Kaisa; Jutila, Topi; Hirvonen, Timo; Mäkinen, Laura K.; Blomgren, Karin; Hyytiä, Tuomas; Klockars, Tuomas

Dizzy triathlete–evidence supporting vestibular etiology

Published in:
SCANDINAVIAN JOURNAL OF MEDICINE AND SCIENCE IN SPORTS

DOI:
10.1111/sms.14041

Published: 01/12/2021

Document Version
Publisher's PDF, also known as Version of record

Published under the following license:
CC BY

Please cite the original version:
Manninen, I. K., Jutila, T., Hirvonen, T., Mäkinen, L. K., Blomgren, K., Hyytiä, T., & Klockars, T. (2021). Dizzy triathlete–evidence supporting vestibular etiology. *SCANDINAVIAN JOURNAL OF MEDICINE AND SCIENCE IN SPORTS*, *31*(12), 2267-2271. https://doi.org/10.1111/sms.14041

This material is protected by copyright and other intellectual property rights, and duplication or sale of all or part of any of the repository collections is not permitted, except that material may be duplicated by you for your research use or educational purposes in electronic or print form. You must obtain permission for any other use. Electronic or print copies may not be offered, whether for sale or otherwise to anyone who is not an authorised user.

Check for updates

Received: 30 January 2021 | Accepted: 23 August 2021

DOI: 10.1111/sms.14041

ORIGINAL ARTICLE

WILEY

Dizzy triathlete–evidence supporting vestibular etiology

Iida-Kaisa Manninen[1] | **Topi Jutila**[1] | **Timo Hirvonen**[1] | **Laura K. Mäkinen**[1] | **Karin Blomgren**[1] | **Tuomas Hyytiä**[2] | **Tuomas Klockars**[1]

[1]Department of Otorhinolaryngology – Head and Neck Surgery, Helsinki University Hospital and University of Helsinki, Helsinki, Finland

[2]Department of Neuroscience and Biomedical Engineering, Aalto University School of Science, Espoo, Finland

Correspondence
Iida-Kaisa Manninen, Kasarmikatu 11-13, FI-00130 Helsinki, Finland.
Email: iida-kaisa.manninen@helsinki.fi

Funding information
The Finnish ORL-HNS Foundation Grant, Grant/Award Number: 2020022; Helsinki University Hospital Research Fund

Dizziness during or after the swimming leg is a common complaint among triathletes. We hypothesized that the dizziness is caused by asymmetrical cooling of the vestibular organ. This caloric response is characterized by involuntary eye movements called nystagmus. Altogether, 125 triathletes completed an electronic questionnaire. Fifteen triathletes who had frequently experienced dizziness during the swimming leg agreed to take part in a cold water swimming test. The test comprised two cold water swimming legs, first without earplugs and then with earplugs to prevent a potential caloric response. Eye movements and possible nystagmus were recorded immediately after the swimming legs. A majority (87%, 109/125) of athletes had experienced dizziness during triathlon races or training. Of these, almost all (97%, 106/109) experienced it during or after swimming. Dizziness affected the triathlon performance in half of the athletes with dizziness (50%, 51/102). Fifteen athletes participated in a cold water swimming test. During the first leg (without earplugs), 11/15 athletes (73%) experienced dizziness. Of these, six had nystagmus (55%), four had uncertain nystagmus (36%), and one did not have nystagmus (9%). Only one of these athletes experienced dizziness during the second leg with earplugs. The prevalence of dizziness among triathletes is notable. A large part of the dizziness is likely to be caused by caloric reaction of the vestibular organ. We recommend earplug usage for triathletes suffering from dizziness during the swimming leg.

KEYWORDS
caloric vestibular reaction, dizziness, nystagmus, open water swimming, triathlon

1 | INTRODUCTION

Triathlon is an endurance sport consisting of swimming, cycling, and running. Due to the nature of the sport, medical complaints are common during races. Dizziness comprises 20% of all medical contacts during half- or full-distance triathlon.[1] In addition, dizziness especially during or after the swimming leg is a common topic in various triathlete Internet forums, eg, Facebook groups. The etiology of dizziness during swimming is unknown: benign paroxysmal positional vertigo, cervicogenic dizziness, and caloric reaction (after mastoidectomy) have all been suggested as the cause of dizziness.[2–5] In addition, motion sickness, orthostatic hypotension, and caloric reaction are common hypotheses in Internet triathlon forums.

Caloric response is caused by asymmetrical warming or cooling of the external auditory canal. This produces stimulation or inhibition of the same-side vestibular organ, resulting in dizziness.[6,7] Caloric response as the cause for dizziness

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2021 The Authors. *Scandinavian Journal of Medicine & Science In Sports* published by John Wiley & Sons Ltd.

during triathlon is supported in Internet forums by the reports of numerous athletes who experience dizziness only in cold water and describe the preventive effect of earplugs.

Caloric response, or any other vestibular cause of vertigo, causes dizziness clinically characterized by involuntary eye movements called nystagmus.[6] Nystagmus may be detected without any equipment, but prevention of gaze fixation makes nystagmus easier to detect. The prevention of gaze fixation is usually achieved by Frenzel's goggles and/or darkness. The prevalence of nystagmus without gaze fixation prevention is 40% in patients with vestibular vertigo. The prevalence increases to 66%–83% with Frenzel's goggles and 100% in total darkness.[8] The direction of nystagmus (defined by the fast phase) correlates with the stimulation or inhibition of the vestibular system.[6,9]

We evaluated the prevalence and etiology of dizziness among triathletes, using a questionnaire to examine the former. We explored the etiology of dizziness utilizing a cold water swimming test with nystagmus recordings; selected athletes were analyzed for nystagmus after a cold water swim with and without earplugs. Our hypothesis was that earplug usage would prevent dizziness by obviating the caloric reaction.

2 | MATERIALS AND METHODS

The Ethics Committee of Helsinki University Hospital (HUS/3494/2018) approved the study protocol. All participants were voluntary adults and gave their informed consent. Patients or the public were not involved in the design, execution, reporting, or dissemination of our research.

2.1 | Questionnaire

We distributed an electronic questionnaire through the Finnish triathlon clubs. The questionnaire consisted of questions concerning training history and possible dizziness during triathlon training or competition. Participants with dizziness were asked about the prevalence, inconvenience, and type of dizziness. They were also asked whether they had experienced dizziness during or after swimming, cycling, or running, and whether swimming in indoor pools or open water makes any difference. Alleviating and exacerbating factors of dizziness, visits to a doctor, and details about their swimming technique were also recorded.

2.2 | Cold water swimming test

Triathletes who had frequently experienced dizziness during the swimming leg were asked to participate in a cold water swimming test. Fifteen triathletes consented to participate. The test consisted of two cold water (max 20°C) swimming legs for a minimum of 5 min each. Average swimming time was 9 min 12 s (SD ± 4 min 18 s) during the first leg and 7 min 30 s (SD ±1 min 48 s) during the second leg. Eleven athletes swam in small lakes, 3 in a sea water pool, and 1 in the Baltic Sea. Average water temperature was 17.4°C (SD ± 2.6°C). The first swimming leg was without earplugs or swimming cap covering the external auditory canals, followed by an identical leg with earplugs. We recorded the eye movements and possible nystagmus immediately after each of the two legs with a mobile phone camera (see supporting information file). The mobile phone was attached to specifically designed swimming goggles that allowed the recording of eye movements and hindered gaze fixation (Figure 1). In addition, the athletes were asked about the sensation of dizziness. Three of the athletes did not experience dizziness or had definite nystagmus after the first leg and did not swim the second leg. One athlete dropped an ear plug during the second leg and was excluded from the second leg analyses.

FIGURE 1 Mobile phone attached to specifically designed goggles was used to record eye movements after cold water swimming legs

2.3 | Nystagmus analyses

A total of 27 eye movement recordings were evaluated by two experienced neurotologists blinded to the sensation of dizziness, use of earplugs, and each other´s evaluations. The neurotologists independently classified the recordings for nystagmus as yes, no, or maybe and its direction as right or left. At least, five beats were considered as

nystagmus. Each recording was shown twice in a random order. Every recording was thus reviewed four times. Four "yes" answers or three "yes" answers and one "maybe" were classified as nystagmus.

2.4 | Statistics

An independent professional consulting statistician from Elisa Appelsiini Oy (Helsinki, Finland) completed all statistical analyses.

3 | RESULTS

3.1 | Questionnaire

We contacted 23 triathlon clubs by e-mail, 15 of which agreed to distribute the questionnaire electronically to its athletes. Thus, we do not know the number of athletes who received the questionnaire. The questionnaire was filled out by 125 triathletes. Some questions were not answered by all of the athletes. Background data of the participants are presented in Table 1. A majority (87%, 109/125) of athletes had experienced dizziness during triathlon races or training and 65% (80/124) had experienced dizziness often or always. Almost all (97%, 106/109) of those with dizziness experienced it during or after swimming, 7% (8/109) during cycling and 6% (6/109) while running. Dizziness was more common in open water (76%, 80/105) than in indoor pools (1%, 1/105). One-fourth (23%, 24/105) of the participants reported dizziness in both milieus.

The duration of dizziness varied from a few seconds to 30 min and it was less than 5 min in the majority (84%, 86/102) of respondents. Of those with dizziness, 79% (86/109) reported noticing exacerbating and 48% (52/109) alleviating factors. Exacerbating factors included waves (48%, 41/86), cold water (45%, 39/86), high-intensity training (22%,19/86), long-duration training (10%, 9/86), water in ear sensation (5%, 4/86), and other (13%, 11/86). Alleviating factors included slowing down or stopping (37%, 19/52), earplug usage (31%, 16/52), habituation (6%, 3/52), removing a wetsuit in sitting position (4%, 2/52), change of swimming technique (4%, 2/52), or other (19%, 10/52).

Of those with dizziness, the dizziness affected the training or race performance in half of the athletes (50%, 51/102) (Figure 2). One-third of athletes with dizziness (31%, 32/102) needed to slow down and 13% (13/102) needed to stop for a while. Three athletes (3%) had fallen, one (1%) had interrupted a race, one (1%) had vomited and interrupted a race, and one (1%) needed to change swimming technique.

3.2 | Cold water swimming test

Fifteen triathletes participated in the cold water swimming test. During the first leg (without earplugs), 11 athletes (73%) experienced dizziness. Of these, six had nystagmus (55%), four had uncertain nystagmus (36%), and one did not have nystagmus (9%). A majority (91%, 10/11) of these athletes did not experience dizziness during the second leg (with ear plugs) and dizziness was more common

TABLE 1 Background data of 125 triathlon athletes

Variable	History of dizziness $n = 109$		No history of dizziness $n = 16$		All $n = 125$		p value
Age, years	43.2 (±9.7)		43.6 (±11.2)		43.3 (±9.9)		0.87
	n	%	n	%	n	%	
Sex, men	51/106	47	8/16	50	59/122	48	0.88
Frequent symptoms of orthostatic hypotension	37/107	35	2/16	13	39/123	32	0.090
Frequent motion sickness	37/109	34	4/16	25	41/125	33	0.57
Previous ear diseases[†]	18/107	17	0/13	0	18/120	15	0.21
Previous ear operations[‡]	11/107	10	0/13	0	11/120	9	0.60
Use of ear plugs during swimming	23/109	21	1/16	6	24/125	19	0.30
Freestyle swimming technique	108/108	100	16/16	100	124/124	100	–
Bilateral breath during swimming	52/109	48	10/15	67	62/124	50	0.16

Note: Athletes with and without dizziness did not differ in weekly training hours or training years. Not all athletes answered each question, which is seen in the table.

[†]Mostly (72%, 13/18) infectious diseases and 11% (2/18) some kind of hearing loss.

[‡]Mostly (73%, 8/11) myringotomy or tympanostomy tubes. No mastoidectomies.

during the first swimming leg ($p = 0.0039$). Results of the swimming test are presented in Table 2.

Each of the 27 eye recordings was analyzed four times. Concerning the presence of nystagmus "yes/maybe/no", the four analyses were unanimous in 65% (17/27) of recordings. The agreement in the direction of nystagmus was 100% (10/10) for recordings with a definite nystagmus. Intra-rater reliability was 0.81 (95% confidence interval 0.63–0.99) and 0.81 (0.66–0.96) for the two neurotologists. Six athletes experienced dizziness and had definite nystagmus after the first swimming leg. In these six athletes, the direction of nystagmus was opposite to the breathing side in five athletes (83%) who used unilateral breath. One athlete (17%) used bilateral breath and had a rightward nystagmus.

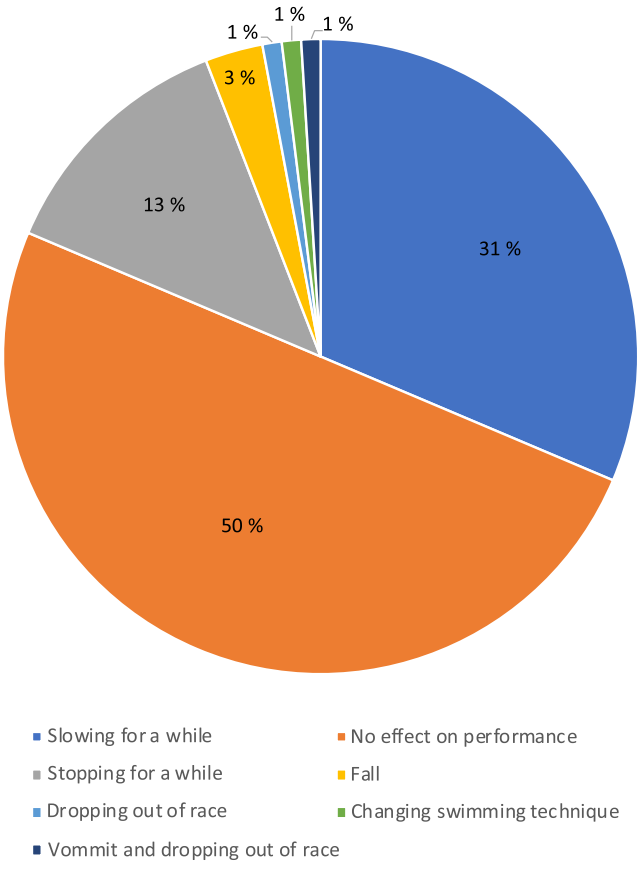

FIGURE 2 Effect of the dizziness on triathlon performance $n = 102$

4 | DISCUSSION

4.1 | Dizziness is a common concern among triathletes

Our study reveals that dizziness is a prevalent complaint among triathletes. The vast majority (87%, 109/125) of the questionnaire respondents had experienced dizziness at least once during triathlon training or racing. Even though there is probably a selection bias, as athletes with dizziness were more likely to participate, the prevalence of dizziness among triathletes is notable.

4.2 | Caloric reaction has a major impact on dizziness among triathletes

Almost all respondents (97%, 106/109) with a history of dizziness had experienced it during or after swimming. Several respondents (36%, 39/109) reported cold water as an exacerbating factor and some (15%, 16/109) had noticed alleviation with ear plugs. We consider these significant findings since the question was open-ended and we expected that all athletes had not tested earplugs during swimming.

Our hypothesis was that by preventing the caloric reaction, earplug usage prevents dizziness during cold water swimming. This hypothesis was supported by the cold

TABLE 2 Dizziness and nystagmus in cold water swimming test

	1st leg (without earplugs) $n = 15$		2nd leg (with earplugs)† $n = 11$	
	n	%	*n*	%
Dizziness	**11/15**	**73**	**1/11**	**9**
Dizziness + nystagmus	6/11	55	1/1	100
Dizziness + uncertain nystagmus	4/11	36		
Dizziness + no nystagmus	1/11	9		
No dizziness	**4/15**	**26**	**10/11**	**91**
No dizziness + nystagmus	1/4	25	2/10	20
No dizziness + uncertain nystagmus	1/4	25	1/10	10
No dizziness + no nystagmus	2/4	50	7/10	70

†Only athletes with dizziness and/or definite nystagmus participated in the 2nd leg. One athlete was excluded from the analyses of the 2nd leg because of dropping an earplug during the 2nd leg.

Bold values are p value for that is 0,0039 (Exact test).

water swimming test since the prevalence of dizziness and nystagmus was high during the first leg without earplugs (40%, 6/15) compared with the second leg with earplugs (9%, 1/11, $p = 0.13$). Almost all triathletes with dizziness (91%, 10/11) reported alleviation with use of earplugs in the cold water swimming test, and dizziness was less common with earplugs ($p = 0.0039$).

Our study demonstrates that a large part of the dizziness among triathletes is aggravated by caloric reaction of the vestibular organ. However, dizziness is often multifactorial and additional factors may have a role. These include high-intensity training with possible hyperventilation and motion sickness with visual-vestibular mismatch, as waves were reported as exacerbating factors and visibility is poor in open water swimming.

4.3 | Perspective

Dizziness accounts for one-fifth of medical visits during half- or full-distance triathlon.[1] Dizziness clearly affects the triathlete's performance, especially in cold and open water conditions. A major part of the dizziness is aggravated by caloric reaction of the vestibular organ and ear canal protection seems to prevent it. Earplug or swimming cap usage is an easy and affordable way to improve triathlon performance and swimming safety. In addition, they may prevent the formation of exostoses.[10] We recommend ear canal protection for all triathletes suffering from dizziness during swimming.

ACKNOWLEDGEMENTS

We thank all triathlon clubs and athletes for help and a positive attitude toward our study. This work was supported by the Helsinki University Hospital Research Fund and The Finnish ORL-HNS Foundation under Grant 2020022.

CONFLICT OF INTEREST

No potential conflict interest was reported by the authors.

DATA AVAILABILITY STATEMENT

Data are available upon reasonable request.

ORCID

Iida-Kaisa Manninen https://orcid.org/0000-0003-4832-3442

REFERENCES

1. Turris SA, Lund A, Bowles RR, Camporese M, Green T. Patient presentations and medical logistics at full and half ironman distance triathlons. *Curr Sports Med Rep*. 2017;16(3):137-143.
2. Selcuk OT, Eraslan A, Osma U, Eren E, Eyigor H, Yilmaz MD. Benign paroxysmal positional vertigo caused by swimming. *Asian J Sports Med*. 2014;5(1):71-72.
3. Aksoy S, Sennaroglu L. Benign paroxysmal positional vertigo in swimmers. *Kulak Burun Bogaz Ihtis Derg*. 2007;17(6):307-310.
4. Heidenreich KD, Beaudoin K, White JA. Cervicogenic dizziness as a cause of vertigo while swimming: an unusual case report. *Am J Otolaryngol*. 2008;29(6):429-431.
5. El-silimy O, Smelt GJC, Bradley PJ. Swimming with a mastoid cavity: what are the risks? *Clin Otolaryngol Allied Sci*. 1986;11(4):209-212.
6. Flint PW, Cummings CW. *Cummings otolaryngology - head and neck surgery : Head and neck surgery*, 3-volume set. Vol, 5th ed. Mosby; 2010:2305-2327.
7. Brookler KH. Simultaneous bilateral bithermal caloric stimulation in electronystagmography. *Laryngoscope*. 1971;81(7):1014-1019.
8. Hirvonen TP, Juhola M, Aalto H. Suppression of spontaneous nystagmus during different visual fixation conditions. *Eur Arch Otorhinolaryngol*. 2012;269(7):1759-1762.
9. Gleeson M, ed. *Scott-brown's otorhinolaryngology, head and neck surgery*. 7th ed. CRC Press; 2008.3727-3728 p.
10. Alexander V, Lau A, Beaumont E, Hope A. The effects of surfing behaviour on the development of external auditory canal exostosis. *Eur Arch Otorhinolaryngol*. 2015;272(7):1643-1649.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Manninen I-K , Jutila T , Hirvonen T , et al. Dizzy triathlete–evidence supporting vestibular etiology. *Scand J Med Sci Sports*. 2021;31:2267–2271. https://doi.org/10.1111/sms.14041