Rev. Otorrinolaringol. Cir. Cabeza Cuello 2024; 84: 11-17

doi: 10.4067/S0718-48162024000100102

RESEARCH ARTICLE

Usefulness of low-cost infrared goggles for the assessment of spontaneous nystagmus

Utilidad de gafas infrarrojas de bajo costo para la evaluación del nistagmo espontáneo

Sofia Waissbluth A.[1], Karina Aracena C.[1,2], Macarena Gallardo C.[2], Francisco García-Huidobro N.[3], Javier Oyarzún A.[1], Anthony Marcotti F.[4,5]

Abstract

Introduction: Due to its precision and simplicity, videonystagmography is the most used technique for evaluating eye movements in patients with vestibular complaints. However, its high cost limits its widespread use. In response, the development of low-cost goggles emerged as an alternative to traditional videonystagmography equipment. **Objetives**: This study aimed to compare the performance between low-cost goggles and videonystagmography in assessing spontaneous nystagmus. **Materials and Methods**: We conducted a cross-sectional study at the Department of Otolaryngology at the Red UC Christus. Patients referred for vestibular evaluation were assessed using both videonystagmography and a prototype of low-cost goggles. Two blinded clinicians with varying levels of expertise reviewed recordings from both tests to identify spontaneous nystagmus. **Results**: Of 104 participants, 56.7% exhibited spontaneous nystagmus detected by videonystagmography. The low-cost goggles demonstrated a concordance of $\kappa = 0.60$ for nystagmus detection and $\kappa = 0.47$ for classification when used by the less experienced clinician. The more experienced clinician achieved a concordance of $\kappa = 0.82$ for detection and $\kappa = 0.73$ for classification. **Conclusion**: While clinical assessments can be conducted without specialized equipment, videonystagmography offers a comprehensive and detailed evaluation, making it the preferred and widely utilized method. Nevertheless, low-cost goggles enable the detection of spontaneous nystagmus, demonstrating satisfactory agreement with videonystagmography.
Keywords: nystagmus, vertigo, vestibular, oculomotor, videonystagmography.

Resumen

Introducción: *Debido a su precisión y simplicidad, la videonistagmografía es la técnica más utilizada para la evaluación de movimientos oculares en pacientes con queja vestibular. Sin embargo, su alto costo limita su utilización. Frente a esto, el desarrollo de gafas de bajo costo se posiciona como una alternativa al equipo tradicional de videonistagmografía.* ***Objetivo:*** *El objetivo de este estudio fue comparar el rendimiento entre gafas de bajo costo y videonistagmografía en la evaluación del nistagmo espontáneo.* ***Material y Métodos:*** *Realizamos un estudio transversal en el Servicio de Otorrinolaringología de la Red UC Christus. Los pacientes derivados para evaluación vestibular fueron evaluados con videonistagmografía y con un prototipo de gafas de bajo costo. Dos clínicos cegados con distinta experiencia revisaron las grabaciones de ambas pruebas en busca de nistagmo espontáneo.* ***Resultados:*** *De 104 participantes, el 56,7% presentó nistagmo espontáneo detectado por videonistagmografía. Las gafas de bajo costo mostraron una concordancia de $\kappa = 0{,}60$ para la detección del nistagmo y $\kappa = 0{,}47$ para la clasificación cuando fueron utilizadas por el clínico menos experimentado. El clínico más experimentado logró una concordancia de $\kappa = 0{,}82$ para la detección y $\kappa = 0{,}73$ para la clasificación.* ***Conclusión:*** *Aunque las evaluaciones clínicas pueden realizarse sin equipo especializado, la videonistagmografía proporciona una evaluación integral y detallada, convirtiéndola en el método preferido y ampliamente utilizado. Sin embargo, las gafas económicas permiten la detección de nistagmo espontáneo, mostrando un acuerdo satisfactorio con la videonistagmografía.*
Palabras clave: *nistagmo, vertigo, vestibular, oculomotor, videonistagmografía.*

[1]Departamento de Otorrinolaringología, Facultad de Medicina, Pontificia Universidad Católica de Chile, Santiago, Chile.
[2]Departamento de Ciencias de la Salud, Carrera de Fonoaudiología, Pontificia Universidad Católica de Chile. Santiago, Chile.
[3]Unidad de Otorrinolaringología, Hospital Naval Almirante Nef, Viña del Mar, Chile.
[4]Escuela de Fonoaudiología, Facultad de Odontología y Ciencias de la Rehabilitación, Universidad San Sebastián, Santiago, Chile.
[5]Programa de Doctorado en Psicología, Escuela de Psicología, Facultad de Humanidades, Pontificia Universidad Católica de Chile, Santiago, Chile.

The authors declare no conflicts of interest.

Received 20 October 2023.
Accepted 11 November 2023.

Corresponding author:
Karina Aracena C.
Departamento de Ciencias de la Salud, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Macul, Santiago, Chile.
Email: karina.aracena@gmail.com

ISSN 0718-4816 versión en línea - ISSN 0716-4084 versión impresa

Introduction

Vertigo and dizziness are common symptoms that lead patients to seek ambulatory care, accounting for a significant number of visits[1]. The lifetime prevalence of significant dizziness is estimated to range from 17 to 30%[2]. A comprehensive evaluation of patients experiencing these symptoms is crucial to determine whether the underlying cause is peripheral or central, as treatment approaches significantly differ depending on the etiology[1]. Accurate data on the incidence and impact of these conditions are also essential for effective healthcare service planning[2].

Considering the high rate of misdiagnosis of dizziness in primary care and emergency departments, it is crucial to provide appropriate training for healthcare professionals to improve patient outcomes and reduce costs[1]. Patients presenting with dizziness in emergency departments typically undergo extensive testing, including disproportionate imaging[4]. Among patients with acute vestibular syndrome, characterized by severe symptoms, seeking emergency care is common. While the majority of these patients suffer from acute peripheral vestibulopathy, such as vestibular neuritis, a small proportion may have a posterior-circulation infarction. Given the importance of distinguishing between these clinical conditions, a three-step bedside examination known as the horizontal head-impulse test (HIT), observation of spontaneous nystagmus, and the alternate cover test for skew deviation ("H.I.N.T.S.") has recently been developed to differentiate between stroke and acute peripheral vestibulopathy[5]. Hence, the importance of observing and recognizing nystagmus cannot be overstated.

Although a negative horizontal-HIT test is highly indicative of a central lesion, its utilization in emergency departments is often limited[6]. However, as a qualitative clinical test, the HIT does not provide objective measurements of the vestibulo-ocular reflex (VOR) gain or corrective saccades[7]. To address this limitation, a more advanced assessment tool called the video HIT (vHIT) has been developed. The vHIT device consists of a high-speed camera mounted on the subject's head with tight-fitting goggles and head velocity sensors, which can detect both overt and covert saccades and quantify VOR gains[7,8]. By utilizing two infrared light-emitting diodes, the vHIT instrument records eye movements during head impulses, making it an invaluable tool for assessing patients with acute vertigo and spontaneous nystagmus[7]. However, it is important to note that vHIT devices are typically only available in specialized dizziness clinics rather than emergency rooms.

Both electronystagmography (ENG) and videonystagmography (VNG) are utilized for recording eye movements[9]. VNG is currently the most widely used method and employs infrared light[10] unlike ENG, which requires electrodes. This shift in preference is primarily due to the speed and simplicity of VNG, as it eliminates the need for electrodes, resulting in quicker and easier testing[9]. VNG is capable of assessing various types of ocular movements, including positional or spontaneous nystagmus, saccades, smooth pursuit, optokinetic and post-caloric nystagmus[9]. However, it is important to note that VNG equipment can be costly and may not be universally accessible in all regions.

To address the limitations associated with the high cost of traditional VNG equipment, the development of infrared goggles has emerged as a solution. These goggles offer a cost-effective alternative while still enabling accurate evaluation of patients with nystagmus. Ceballos-Lizarraga and Rivera have created an online manual detailing the assembly process for these low-cost infrared goggles, which can be constructed for approximately $51 USD (https://www.vestibularproject.org/vni)[11]. Despite its availability, no studies have been conducted to validate this device.

Objective

The aim of this study was to compare the performance of low-cost goggles (LCG) with traditional VNG for assessing spontaneous nystagmus and to validate their use as a tool for centers with limited resources to acquire expensive instruments.

Materials and Methods

A cross-sectional study with an analytical scope was conducted at the Department of Otolaryngology of Red UC Christus. The study protocol was approved by the Research Ethics Committee at the Pontificia Universidad Católica de Chile with research protocol N°180806011. Informed consent was obtained from all participants prior to their enrollment in the study. Both the protocol and the results were reported using STROBE statement guidelines[12].

All adult patients referred for vestibular evaluation between October 2018 and February 2020 were eligible for this study. A total of 109 patients were referred for vestibular evaluation during this period, of whom five declined to participate. The final sample consisted of 104 subjects, 70 (67.3%) women, with a mean age of 47.1 years (SD 20.5).

The LCG were assembled according to the instructions provided in the online manual available at https://www.vestibularproject.org/vni **(Figure 1)**[11]. All patients underwent vestibular assessment with both VNG (VisualEyes™ 515 from Interacoustic) and LCG to identify the presence or absence of spontaneous nystagmus. Nystagmus was assessed in central, lateral, left, right, up, and down gaze. The same clinician performed both assessments and recorded them on video for subsequent analysis. **Figure 2** illustrates the quality and resolution of the LCG. All enrolled subjects were requested to complete a 5-point Likert-type questionnaire assessing their subjective comfort level while undergoing VNG and LCG testing. The available response options included: very uncomfortable, uncomfortable, neutral, comfortable, and very comfortable.

All video recordings were independently analyzed by two additional clinicians who were blinded to the testing method used (VNG or LCG). Both clinicians were professionals in the field of otoneurology, but with different levels of expertise. Clinician 1 (C1) had three years of experience in vestibular assessment, while Clinician 2 (C2), who was considered an expert in the field, had over ten years of experience.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 24.0 (IBM software), using descriptive statistics, chi-square test to evaluate the association between parametric variables. Cohen's kappa coefficient (κ) was used to assess the agreement between the gold standard VNG equipment and the two raters using the LCG. The alpha level for all statistical tests was set at 0.05.

Results

Nystagmus was detected in 59 participants using the VNG equipment, accounting for 56.7% of the cases. When using the LCG, C1 reported nystagmus in 64.4% of the cases, while C2 reported it in 55.7% of the cases. The interrater reliability analysis between the VNG test and each rater yielded a Cohen's kappa coefficient (κ) of 0.60 for C1 and 0.82 for C2.

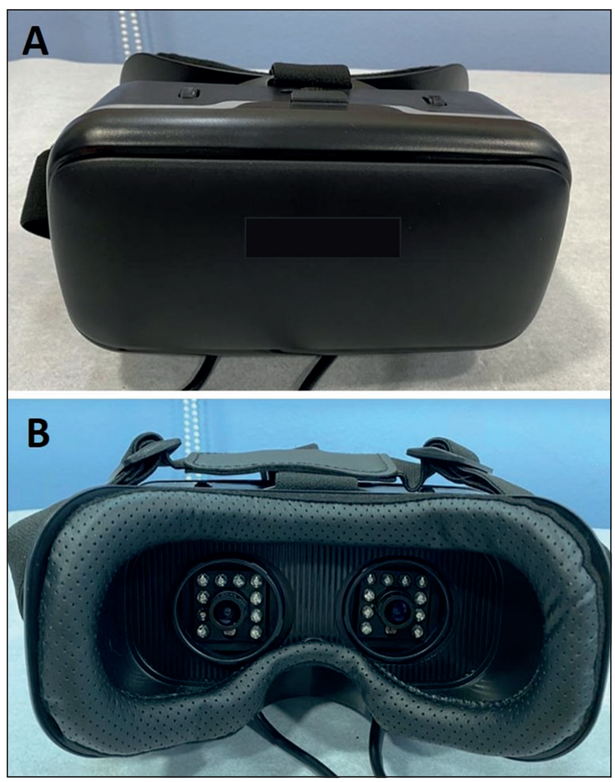

Figure 1. Goggle design. **A:** frontal view of the device. **B:** inner part of the device, cushioning was added around the periorbital area for comfort.

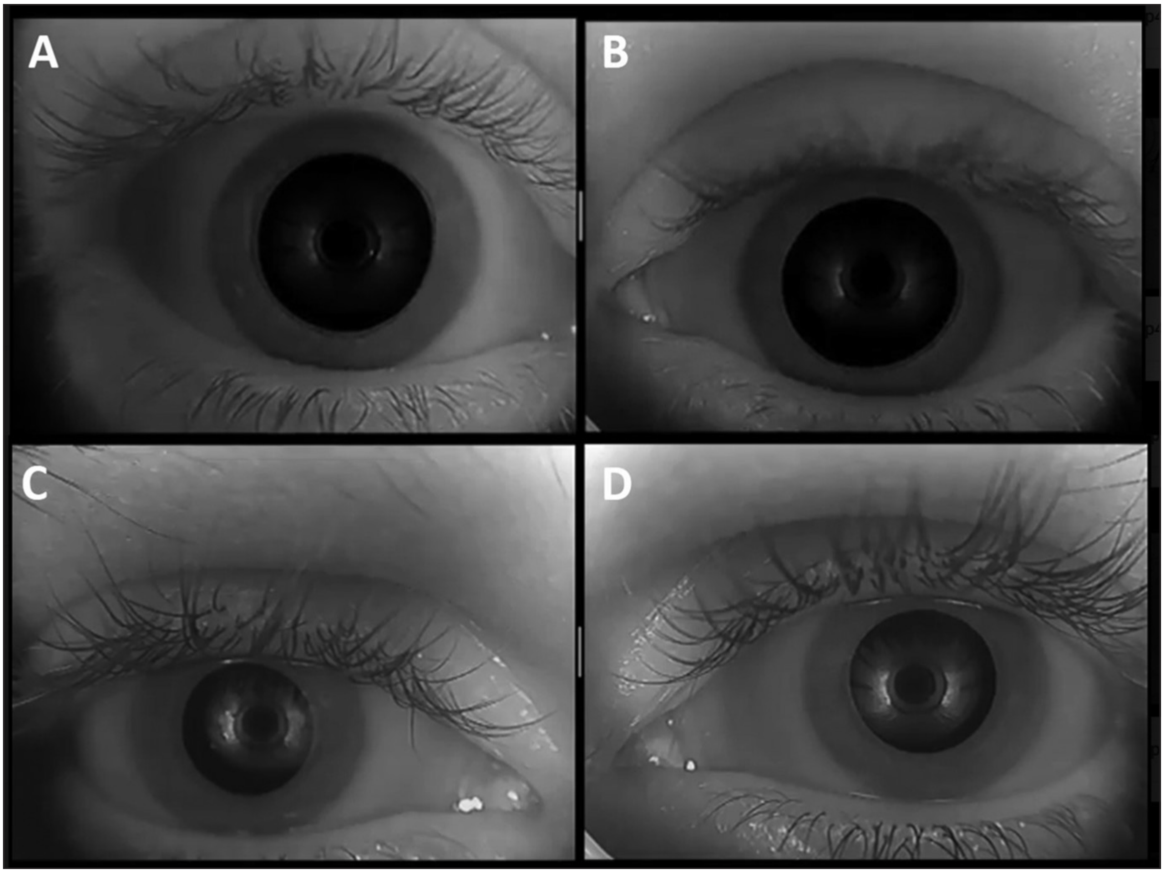

Figure 2. Two examples of visualization of the eyes. A (right eye) and B (left eye) are for one patient; C (right eye) and D (left eye) are from another patient. Good level of visualization is obtained with the LCG.

These results indicate a moderate agreement for nystagmus detection by C1 and an almost perfect agreement by C2.

Furthermore, the raters were asked to classify each nystagmus according to its presence, grade (if peripheral), or potential central origin. The analysis revealed a statistically significant association between the presence of nystagmus and this multi-level classification for both raters ($p < 0.0001$). The inter-rater reliability analysis for nystagmus grade classification between the VNG test and each rater showed a Cohen's kappa coefficient (κ) of 0.47 for C1 and 0.73 for C2. These findings indicate a moderate agreement for nystagmus grade classification by C1 and a substantial agreement by C2.

In terms of comfort, the survey results revealed that a high proportion of patients found the VNG goggles to be comfortable or very comfortable, with 93.1% reporting positive feedback. On the other hand, the comfort level of the LCG was not as favorable, with only 49.4% of participants stating that they were comfortable or very comfortable with the device.

Discussion

The evaluation of eye movements has been an essential part of specialized otoneurological assessment for many years, and more recently, it has also emerged as a critical element for the differential diagnosis of peripheral vestibular pathology from central conditions in emergency departments. Despite the existence of numerous commercial systems and devices available for these purposes, cost remains a limiting factor that hinders accessibility. This has motivated a large number of research teams worldwide to design low-cost prototype devices for these purposes.

In France, Vitte et al. developed a device consisting of infrared cameras mounted on a frame similar to diving goggles, which allowed for the detection of spontaneous nystagmus in a bedside evaluation[13]. Similarly, in Japan, Funabiki et al. developed a similar device and reached similar conclusions regarding its utility in bedside examinations[14]. While both reports highlight the potential usefulness of such devices in general clinical settings, the authors did not provide direct comparisons with standard evaluation methods or commercial devices, nor did they report estimates of agreement or diagnostic accuracy.

Baba et al. conducted a study in Japan to assess the effectiveness of an infrared CCD camera for detecting spontaneous nystagmus compared to Frenzel goggles, with ENG measurements as the reference[15]. The authors reported that the infrared CCD cameras detected all cases of nystagmus, in contrast to Frenzel goggles, which only detected one-third of the cases. Furthermore, they suggested that their device allows for more precise analysis compared to ENG, as the latter can only record eye movements in two dimensions. In Spain, Murueta-Goyena and Rodríguez compared an infrared camera device with a commercial ENG system[16]. The authors described that their device provided advantages in visualizing the rotary component of nystagmus and avoided interference from visual stimuli during the evaluation.

In the United Kingdom, West et al. conducted a similar study, using ENG as the baseline measure to compare the ophthalmoscope, Frenzel lenses, and infrared video-Frenzel lenses in detecting peripheral vestibular nystagmus[17]. The video-Frenzel goggles achieved a sensitivity of 85% and a specificity of 65%. The authors reported that most peripheral disorders were diagnosed in their clinic using these goggles, without the need for ENG or VNG. In Italy, Guidetti et al. compared three low-cost methods for detecting spontaneous, positional, and head-shaking nystagmus in a group of patients evaluated through a battery of computerized oculographic tests. They compared direct observation of the patient's eyes, Frenzel lenses, and a videonystagmoscope[18]. The videonystagmoscope consisted of a mask with infrared light-emitting diodes and two infrared CCD cameras connected to a portable video monitor. They reported that the videonystagmoscope achieved the best diagnostic accuracy, with a sensitivity of 84.2% and a specificity of 91.6%.

To our understanding, this is the first study to assess the level of agreement between a low-cost device and a commercial system using a concordance index, taking into account the evaluator's experience. The clinician with 3 years of experience (C1) achieved substantial agreement ($k = 0.60$) for nystagmus detection and moderate agreement ($k = 0.47$) for its classification. On the other hand, the clinician with 10 years of experience (C2) achieved excellent agreement ($k = 0.82$) and substantial agreement ($k = 0.73$) for nystagmus detection and classification, respectively. These results suggest a high level of agreement between devices for nystagmus detection regardless of the evaluator's experience. However, the classification of nystagmus was indeed associated with the clinicians' expertise ($p < 0.0001$). This is not surprising as the classification of nystagmus, without objective measurements, requires more advanced knowledge and experience in the clinical field.

The findings of this study align with previous research, indicating a general agreement on the clinical usefulness of low-cost infrared camera devices. However, there is a lack of studies that provide comprehensive construction details[13–18]. While research teams in South Korea[19,20], the Philippines[21], and Spain[22] have described the required components to varying extents, none of their publications offer a detailed assembly manual, making replication challenging. In this study, we utilized a freely available online manual that not only provides information on component sourcing but also presents step-by-step assembly instructions, addressing this limitation[11].

While the LCG cannot be considered a direct replacement for VNG equipment, they serve as a valuable and easily assembled tool for the detection of spontaneous nystagmus in settings where access to sophisticated testing equipment is limited. Although the survey revealed that the comfort level of the LCG used in this study was comparatively lower than that of VNG goggles, ongoing efforts are being made to optimize their design. Considering their cost-effectiveness and potential impact, the LCG should be regarded as a significant supplementary resource in the field of neurotology, particularly in underserved regions.

Conclusions

An accurate assessment of eye movements such as spontaneous nystagmus is crucial in reaching a correct diagnosis, especially to differentiate central from peripheral etiologies. While videonystagmography is the most used method worldwide for recording eye movements, the cost of the equipment may be high for certain parts of the world. The findings of the present study support the feasibility and usefulness of the low-cost device as a reliable tool for the initial detection of nystagmus. However, it is important to note that the accurate interpretation and classification of nystagmus still heavily rely on the clinical expertise of the evaluator. The level of comfort of the current LCG will be improved by adjusting the current design.

Acknowledgements

We wish to thank Dr Ricardo Ceballos Lizarraga for the creation of the low cost googles and for sharing his assembly manual online, free of charge.

Bibliography

1. Neuhauser H. The epidemiology of dizziness and vertigo. In: Furman J, Lempert T, eds. *Handbook of Clinical Neurology*. Vol 137. Elsevier B.V.; 2016:67-82. https://doi:10.1016/B978-0-444-63437-5.00005-4
2. Murdin L, Schilder A. Epidemiology of balance symptoms and disorders in the community: A systematic review. *Otol Neurotol*. 2015;36(3):387-392. https://doi:10.1097/MAO.0000000000000691
3. Neuhauser H. Epidemiology of vertigo. *Curr Opin Neurol*. 2007;20(1):40-46. https://doi:10.1097/WCO.0b013e328013f432
4. Newman-Toker D, Hsieh Y, Camargo C, Pelletier A, Butchy G, Edlow J. Spectrum of dizziness visits to US emergency departments: Cross-sectional analysis from a nationally representative sample. *Mayo Clin Proc*. 2008;83(7):765-775. doi:10.4065/83.7.765
5. Kattah J, Talkad A, Wang D, Hsieh Y, Newman-Toker D. HINTS to diagnose stroke in the acute vestibular syndrome: Three-step bedside oculomotor examination more sensitive than early MRI diffusion-weighted imaging. *Stroke*. 2009;40(11):3504-3510. https://doi:10.1161/STROKEAHA.109.551234
6. Mcdowell T, Moore F. The under-utilization of the head impulse test in the emergency department. *Can J Neurol Sci*. 2016;43(3):398-401. https://doi:10.1017/cjn.2015.330
7. MacDougall H, Weber K, McGarvie L, Halmagyi G, Curthoys I. The video head impulse test: Diagnostic accuracy in peripheral vestibulopathy. *Neurology*. 2009;73(14):1134-1141. https://doi:10.1212/WNL.0b013e3181bacf85
8. Halmagyi G, Chen L, MacDougall H, Weber K, McGarvie L, Curthoys I. The video head impulse test. *Front Neurol*. 2017;8:258. https://doi:10.3389/fneur.2017.00258
9. Ganança M, Caovilla H, Ganança F. Electronystagmography versus videonystagmography. *Braz J Otorhinolaryngol*. 2010;76(3):399-403. https://doi:10.1590/S1808-86942010000300021
10. Furman J, Goldstein A. Vertigo. In: Swaiman K, Ashwal S, Ferriero D, et al., eds. *Vertigo in Swaiman's Pediatric Neurology: Principles and Practice*. 6th ed. Elsevier; 2017:52-57. https://doi: 10.1016/B978-0-323-37101-8.00008-4
11. Ceballos R, Rivera S. Infrared Videonystagmoscope Manual v4.0 [The Vestibular Project Infrared Videonystagmoscope Web site]. June 1, 2020. Available at: https://www.vestibularproject.org/vni. Accessed June 30, 2020
12. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *The Lancet*. 2007;370(9596):1453-1457. https://doi:10.1016/S0140-6736(07)61602-X
13. Vitte E, Sémont A, Freyss G, Soudant J. Videonystagmoscopy: Its use in the clinical vestibular laboratory. *Acta Otolaryngol*. 1995;115(S520):423-426. https://doi:10.3109/00016489509125288
14. Funabiki K, Naito Y, Honjo I. Light-weight and low-cost infrared CCD eye monitoring system designed for routine vestibular clinic use. *Acta Otolaryngol*. 1997;117(528):67-69.

15. Baba S, Fukumoto A, Aoyagi M, Koizumi Y, Ikezono T, Yagi T. A comparative study on the observation of spontaneous nystagmus with Frenzel glasses and an infrared CCD camera. *J Nippon Med Sch*. 2004;71(1):25-29. https://doi:10.1272/jnms.71.25
16. Murueta-Goyena F, Rodríguez F. Videonistagmoscopia simplificada. *Acta Otorrinolaringológica Español*. 1998;49(3):253-255.
17. West P, Sheppard Z, King E. Comparison of techniques for identification of peripheral vestibular nystagmus. *Journal of Laryngology and Otology*. 2012;126(12):1209-1215. https://doi:10.1017/S0022215112002368
18. Guidetti G, Monzani D, Rovatti V. Clinical examination of labyrinthine-defective patients out of the vertigo attack: sensitivity and specificity of three low-cost methods. *Acta Otorhinolaryngol Ital*. 2006;26(2):96-101.
19. Park J, Kong Y, Nam Y. A low-cost video-oculography system for vestibular function testing. *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*. Published online 2017:4078-4081. https://doi:10.1109/EMBC.2017.8037752
20. Kong Y, Lee S, Lee J, Nam Y. A head-mounted goggle-type video-oculography system for vestibular function testing. *EURASIP J Image Video Process*. 2018;2018:28. https://doi:10.1186/s13640-018-0266-x
21. Guevarra J, Chiong C. Low Cost Video Frenzel Goggles (LCVFG). *Philippine Journal of Otolaryngology Head and Neck Surgery*. 2004;19(1-2):93-97.
22. Betances F, Lopez T, Rodríguez V, De León N. Prototipo de video frenzel-video head impulse test de bajo coste. *Ciencia y Salud*. 2019;3(3):7-13. https://doi:10.22206/cysa.2019.v3i3.pp7-13