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Head Roll-Tilt Subjective Visual Vertical Test in the Diagnosis of Persistent Postural-Perceptual Dizziness

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Objective: To examine the validity of head roll-tilt subjective visual vertical (HT-SVV) in diagnosing persistent postural-perceptual dizziness (PPPD).

Study Design: Retrospective review.

Setting: Tertiary referral center.

Patients: Sixty-one patients with PPPD, 10 with unilateral vestibular hypofunction (UVH), and 11 with psychogenic dizziness (PD), showing chronic vestibular symptoms for >3 months.

Interventions: Head-tilt perception gain (HTPG, i.e., mean perceptual gain [perceived/actual tilt angle]) during right or left head tilt of approximately 30° (HT-SVV) and conventional head-upright SVV (UP-SVV) were measured. Bithermal caloric testing, cervical and ocular vestibular-evoked myogenic potentials (cVEMP and oVEMP), and posturography were conducted.

Main Outcome Measures: Multiple comparisons were performed for the HT-SVV and other vestibular tests among the disease groups. A receiver operating characteristic curve was created to predict PPPD using HTPG.

Results: HTPG was significantly greater in the PPPD group than in the UVH and PD groups. There were no significant differences in UP-SVV, cVEMP, oVEMP, and posturography (foam ratio and Romberg ratio on foam) among the disease groups, while the UVH group had the highest canal paresis compared to the other two groups. The area under the curve of the receiver operating characteristic curve for predicting PPPD was 0.764, and the HTPG value of 1.202 had a specificity of 95.2% for diagnosing PPPD.

Conclusions: While conventional vestibular tests including UP-SVV, VEMPs, and posturography did not show abnormalities in PPPD, high HTPG in the HT-SVV test, an excessive perception of head tilt, can be a specific marker for discriminating PPPD from other chronic vestibular diseases. **Key Words:** Head roll-tilt subjective visual vertical—Hypersensitivity—Persistent postural-perceptual dizziness—Receiver operating characteristic curve.

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Persistent postural-perceptual dizziness (PPPD) is a chronic vestibular syndrome characterized by vestibular symptoms lasting >3 months, which is typically preceded

by acute vestibular disorders (1). The core vestibular symptoms of PPPD are dizziness, unsteadiness, or nonspinning vertigo, which are exacerbated by upright posture/walking, active or passive motion, and exposure to moving or complex visual stimuli (1). Recent reports using the diagnostic criteria for PPPD established by the Barany Society in 2017 demonstrated that PPPD is present in approximately 20% of all dizzy patients in neurologic practice (2,3). The diagnosis is based entirely on the typical clinical symptoms, as no clinical laboratory test has been accepted for PPPD. The absence of clinical laboratory tests might be one of the factors that make PPPD diagnosis difficult.

Postural control is maintained by vestibular, visual, and somatosensory systems. If one of these sensory systems is impaired, other sensory system(s) substitutes it by mechanisms called sensory reweighting. Immediately after acute vestibular insults, postural control shifts to visual and/or somatosensory dependence to compensate for impaired vestibular function (4,5). These shifts to visual and/or somatosensory dependence are beneficial

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initially but should revert to normal after removal of the precipitant or after compensation. However, in patients with PPPD, a high level of vigilance is maintained, and postural control remains visually and/or somatosensory dependent (i.e., over adaptation), which could cause excessive responses to visual stimuli and body motions (6).

The subjective visual vertical (SVV), proposed by Witkin and Ash (7), is a psychophysical paradigm used for measuring the visually perceived direction of the gravitational vertical using a visual line stimulus. SVV reflects the function of gravity perception pathways from otoliths in the vestibular periphery to the central vestibular circuits (8–10). Head roll-tilt SVV (HT-SVV) is measured during head roll-tilt, which is more sensitive to gravity perception than the conventional head-upright SVV (UP-SVV) (11,12). HT-SVV measures the participant's perception of the head-tilt angle compared to the actual head-tilt angle. Therefore, we hypothesized that HT-SVV could be a clinical measure for the assessment of perceptual hypersensitivity in PPPD that may differentiate between PPPD and other chronic vestibular diseases. In this study, we compared the validity of HT-SVV and conventional vestibular tests in the accurate diagnosis of patients with chronic vestibular symptoms, including PPPD, unilateral vestibular hypofunction (UVH), and psychogenic dizziness (PD).

MATERIALS AND METHODS

Patients

This study was approved by the Institutional Review Board of Niigata University Medical and Dental Hospital (#2018-0345). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from patients at the time of inclusion in the study, authorizing the anonymous use of data for further studies. This study included 61 patients with PPPD, 10 patients with UVH, and 11 patients with PD who had visited the Department of Otolaryngology Head and Neck Surgery at Niigata University Medical and Dental Hospital with complaints of chronic dizziness lasting >3 months and in whom HT-SVV was assessed between October 2018 and August 2020.

PPPD was diagnosed using the Barany Society criteria (1). UVH was defined as unilateral abnormal values in the caloric testing or video head-impulse test, according to the report by Starkov et al. (13). In this study, PD included panic disorder (n = 3) and generalized anxiety disorder (n = 8) diagnosed according to the Diagnostic and Statistical Manual of Mental Disorders-5 (14).

The precipitating conditions for patients with PPPD or UVH are shown in the Supplemental Table, <http://links.lww.com/MAO/B323>. Among the patients with PPPD or UVH, one PPPD patient was diagnosed with depression at the time of the first visit to our department and received psychiatric treatment. There were no other cases with psychiatric comorbidities. All patients in the UVH group showed head-shaking nystagmus and had head-motion-induced dizziness, while visually induced dizziness or persistent dizziness that occurs when they are stationary was not present. In the PD group, four cases had tinnitus, three had unilateral low-tone sensorineural hearing loss, and two had

hyperacusis. Five patients with PPPD and one patient with PD had a migraine. At the time of the HT-SVV test, nine patients with PPPD and four patients with PD had been taking antidepressants such as selective serotonin reuptake inhibitors, serotonin and noradrenaline reuptake inhibitors, and noradrenergic and specific serotonergic antidepressants for more than 3 months.

Head Roll-Tilt Subjective Visual Vertical (15)

HT-SVV was determined using the HT-SVV examination system (UNIMEC, Japan) and the SVV and head roll-tilt angle (HTA), which is the tilt angle of the head relative to the gravity axis, were measured simultaneously. During the experiment, the participant was instructed to sit on a chair approximately 60 cm from a bar-display box and wear goggles to exclude any visual information other than that of the bar (7-cm length × 0.2-cm width) on display. Concurrently, the HTA was measured using a linear accelerometer attached to the goggles. At the beginning of each experiment, the participant was instructed to tilt the head slowly rightward or leftward until the experimenter instructed them to stop (approximately -30° , 0° , or 30°) to keep the trunk upright and to keep the eyes closed. After the head was kept tilted for 5 to 10 s, the participant was instructed to open the eyes and record the SVV using the bar, which was randomly oriented on the screen. The participant adjusted the bar clockwise or counterclockwise to match his/her perceived direction of gravity, using a keypad programmed to change the bar orientation by 1° per keystroke. The SVV was measured 14 times (four times each for the -30° and 30° tilts and six times for the 0° tilt) in a pseudo-random order.

The UP-SVV was measured six times in relation to the earth vertical with an accuracy of 0.1° , and the average value of the six measurements was used.

Head-tilt perception (HTP) is defined as the angle of the head tilt from the SVV (Fig. 1). Therefore, the HTP can be calculated using the following equation: $\text{HTP}(\text{degrees}) = \text{HTA} - \text{SVV}$

The slope in the regression equations for UP-SVV and HT-SVV, when the *x*-axis represents the HTA, and the *y*-axis represents the HTP, was defined as the head-tilt perception gain (HTPG). An HTPG value greater than 1.0 indicates that the participant felt and recorded a greater head-tilt angle than the actual, that is, an overestimation. An HTPG value less than 1.0 indicates the opposite effect, that is, an underestimation. The HTPG is calculated for the right, and left head tilts to obtain the right and left HTPGs. While the mean of the right and left HTPGs was defined as the HTPG value, HTPG laterality between the left and right HTPGs was defined by the following equation: $\text{HTPG laterality}(\%) = \frac{(\text{left HTPG} - \text{right HTPG})}{(\text{left HTPG} + \text{right HTPG})} \times 100$

Based on the results of previous experiments with healthy participants, UP-SVV $< 2.5^\circ$, mean HTPG 0.80–1.25, and HTPG laterality $< 10\%$ were considered normal (15).

Bithermal Caloric Testing

Bithermal caloric testing was performed using air at 26°C and 45°C each for 60 seconds. Each external auditory canal was stimulated twice with a 5-minute interval between the stimulations. The maximum slow-phase velocity was measured using electronystagmography, and canal paresis (CP) was calculated using Jongkee's index formula (16). A CP value of $>20\%$ was considered to indicate significant unilateral caloric weakness.

Cervical and Ocular Vestibular-Evoked Myogenic Potentials

Cervical and ocular vestibular-evoked myogenic potentials (cVEMP and oVEMP) were determined using Neuropack® system (Nihon Kohden, Japan) to assess the saccular and utricular function, respectively. Clicks (0.1-ms rarefactive square waves of

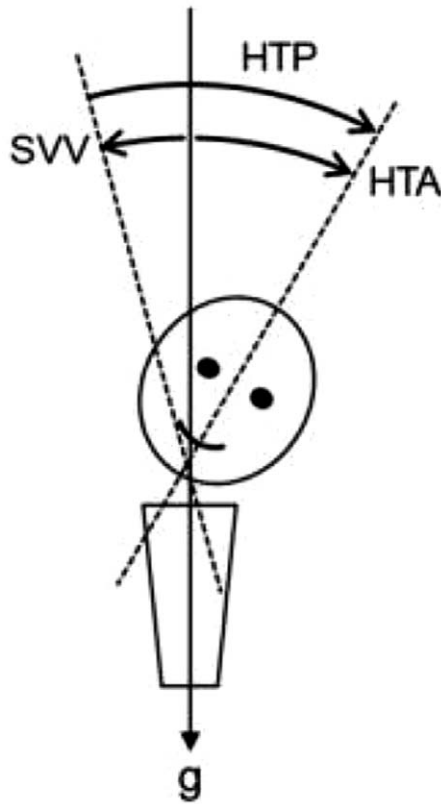


FIG. 1. The head roll-tilt subjective visual vertical (15). The HTP is defined as the perceived angle of the head tilt from the SVV. *g*, gravity; HTA, head roll-tilt angle; HTP, head-tilt perception; SVV, subjective visual vertical.

105-dB nHL) were used to induce cVEMP. To record the oVEMP, 500-Hz tone bursts (4-ms plateau and 1-ms rise and fall) generated by a hand-held electromechanical vibrator (Minishaker®, Bruel & Kjaer, Denmark) were used as bone-conducted stimuli. Amplitudes and latencies were measured at response peaks, which occurred at approximately 13 and 23 millisecond for the cVEMP and 10 and 15 millisecond for the oVEMP, respectively, depending on the stimulus. The difference between the peak amplitudes was used to obtain the peak-to-peak amplitude. To compare the two ears, the asymmetry ratio (AR) was calculated using the formula: $AR = (\text{right} - \text{left}) / (\text{right} + \text{left}) \times 100$ (%) in the raw peak-to-peak amplitude (17). An $|AR| > 33.3\%$ was defined as unilateral saccular (cVEMP) or utricular (oVEMP) dysfunction.

Posturography

The patients underwent static posturography on a solid or rubber foam surface using Gravicoda® (ANIMA Corp., Japan), with open as well as closed eyes. The foam ratio (posturography with/without foam) determined with closed eyes was used as an indicator of somatosensory dependence of postural control, whereas the Romberg ratio on foam was used as an indicator of visual dependence (5).

Statistics

The Kruskal–Wallis test followed by the post-hoc Dunn–Bonferroni test was performed to compare the UP-SVV, mean

HTPG, HTPG laterality, and results of vestibular tests among the three groups (PPPD, UVH, and PD).

The Mann–Whitney *U* test was performed to compare the UP-SVV, HTPG on the affected side (affected-HTPG), HTPG on the healthy side (healthy-HTPG), HTPG laterality, and results of vestibular tests between 21 patients with PPPD and UVH ($CP > 20\%$, PPPD-UVH subgroup) and the 10 patients with UVH. The Mann–Whitney *U* test was also performed to compare the UP-SVV, mean HTPG, HTPG laterality, and results of vestibular tests between 35 patients with PPPD and no vestibular hypofunction ($CP \leq 20\%$ and/or normal video head-impulse test, PPPD-NVH subgroup) and the 11 patients with PD. Vestibular tests were not performed for five patients with PPPD who were excluded from the analysis.

Finally, to evaluate the diagnostic ability of HT-SVV to differentiate PPPD from UVH and PD, a receiver operating characteristic (ROC) curve was constructed, and the area under the curve (AUC) was calculated.

All statistical analyses were performed using SPSS for Windows (version 26.0). Statistical significance was set at $p < 0.05$. The effect sizes of 0.10, 0.30, and 0.50 for both Cramer's *V* and *r* were considered to be small, medium, and large, respectively.

RESULTS

The PPPD group included 20 men and 41 women, the UVH group included seven men and three women, and the PD group included two men and nine women. The number of men was significantly greater in the UVH group than in the other two groups (Fisher's exact test, $p = 0.039$, Cramer's *V* = 0.29). The mean age of patients in the UVH group (65.7 yrs, standard deviation [SD]: 8.1 yrs) was significantly greater than that of patients in the PPPD group (49.1 yrs, SD: 14.2 yrs) (Dunn test, $p = 0.004$, $r = 0.38$) and in the PD group (45.8 yrs, SD: 17.1 yrs) (Dunn test, $p = 0.010$, $r = 0.35$).

As shown in Table 1, the Kruskal–Wallis test demonstrated significant differences in mean HTPG and CP, but not in UP-SVV, HTPG laterality, cVEMP, oVEMP, foam ratio, and Romberg ratio on foam. The post-hoc Dunn–Bonferroni test (Fig. 2) revealed that the mean HTPG of the PPPD group (mean: 1.203, SD: 0.226) was significantly greater than that of the UVH group (mean: 1.056, SD: 0.126; $p = 0.042$, $r = 0.29$) and the PD group (mean: 1.030, SD: 0.097; $p = 0.009$, $r = 0.35$). The CP of the UVH group (mean: 71.6, SD: 33.7) was significantly greater than that of the PPPD group (mean: 22.9, SD: 25.1; $p = 0.005$, $r = 0.37$) and the PD group (mean: 7.91, SD: 3.47; $p = 0.002$, $r = 0.40$).

Table 2 shows the results of the Mann–Whitney *U* test for UP-SVV, affected-HTPG, healthy-HTPG, HTPG laterality, and findings of vestibular tests between the PPPD-UVH subgroup and the UVH group. The affected-HTPG of patients in the PPPD-UVH subgroup (mean: 1.280, SD: 0.314) was significantly greater than that of patients in the UVH group (mean: 1.030, SD: 0.117; $p = 0.003$, $r = 0.52$). No significant differences were observed in UP-SVV, healthy-HTPG, HTPG laterality, CP, cVEMP, oVEMP, foam ratio, and Romberg ratio on foam.

TABLE 1. Results of the Kruskal–Wallis test

Variables	PPPD (n = 61) Mean ± SD	UVH (n = 10) Mean ± SD	PD (n = 11) Mean ± SD	<i>p</i>
UP-SVV, degree	1.72 ± 1.44	2.48 ± 1.33	1.55 ± 0.84	0.141
Mean HTPG	1.203 ± 0.226	1.056 ± 0.126	1.030 ± 0.097	0.001**
HTPG laterality, %	4.81 ± 4.44	4.62 ± 3.54	4.28 ± 3.47	0.947
CP, %	22.9 ± 25.1	71.6 ± 33.7	7.91 ± 3.47	0.001**
cVEMP (asymmetry ratio), %	28.9 ± 32.1	33.5 ± 29.5	23.4 ± 28.6	0.493
oVEMP (asymmetry ratio), %	21.5 ± 26.6	42.0 ± 48.2	23.1 ± 23.6	0.820
Foam ratio	2.11 ± 0.65	3.72 ± 2.17	2.03 ± 0.61	0.103
Romberg ratio on foam	1.90 ± 0.53	2.40 ± 0.81	1.91 ± 0.73	0.213

CP, canal paresis; cVEMP and oVEMP, cervical and ocular vestibular-evoked myogenic potentials; HTPG, head-tilt perception gain; PD, psychogenic dizziness; PPPD, persistent postural-perceptual dizziness; SD, standard deviation; UP-SVV, upright subjective visual vertical; UVH, unilateral vestibular hypofunction.

**Values indicate statistical significance, *p* < 0.01.

Table 3 shows the results of the Mann–Whitney *U* test for UP-SVV, mean HTPG, HTPG laterality, and findings of the vestibular tests between the PPPD-NVH subgroup and the PD group. The mean HTPG of patients in the PPPD-NVH subgroup (mean: 1.175, SD: 0.178) was significantly greater than that of patients in the PD group (mean: 1.030, SD: 0.097; *p* = 0.007, *r* = 0.39). No significant differences were observed in UP-SVV, HTPG laterality, CP, cVEMP, oVEMP, foam ratio, and Romberg ratio on foam.

Figure 3 shows the ROC curve for the mean HTPG. The AUC of the ROC curve and the cut-off point obtained using the Youden index (sensitivity + specificity-1) for diagnosing PPPD are also presented. The AUC of the ROC curve was 0.764 (95% confidence interval: 0.652 to 0.876), and the mean HTPG of 1.042 and 1.202 had the best sensitivity (mean HTPG of 1.042: 83.6%; mean HTPG of 1.202: 44.3%) and specificity (mean HTPG of 1.042: 57.1%; mean HTPG of 1.202: 95.2%) for diagnosing PPPD.

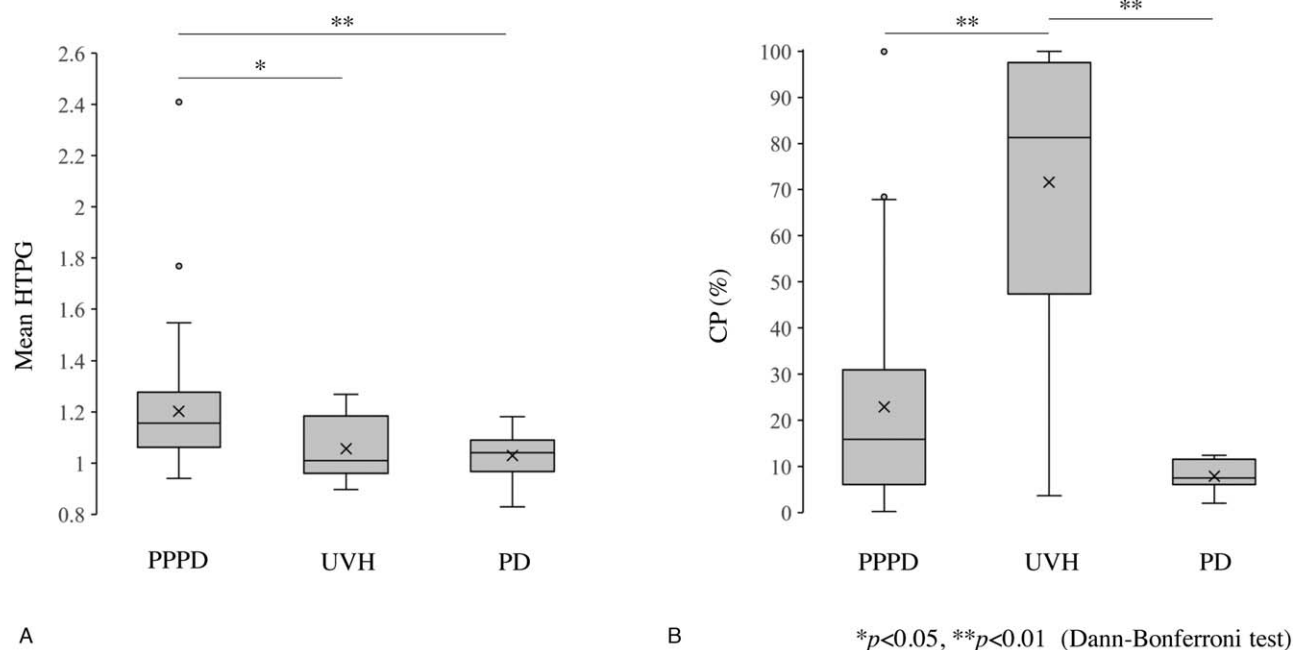


FIG. 2. Comparisons of the mean head-tilt perception gain (HTPG) and canal paresis (CP) among the three groups. *A*) The mean HTPG of patients in the persistent postural-perceptual dizziness (PPPD) group (mean: 1.203, standard deviation [SD]: 0.226) was significantly greater than that of patients in the unilateral vestibular hypofunction (UVH) group (mean: 1.056, SD: 0.126; *p* = 0.042, *r* = 0.29) and the psychogenic dizziness (PD) group (mean: 1.030, SD: 0.097; *p* = 0.009, *r* = 0.35). *B*) The CP of patients in the UVH group (mean: 71.6, SD: 33.7) was significantly greater than that of patients in the PPPD group (mean: 22.9, SD: 25.1; *p* = 0.005, *r* = 0.37) and the PD group (mean: 7.91, SD: 3.47; *p* = 0.002, *r* = 0.40).

TABLE 2. Comparisons between the persistent postural-perceptual dizziness (PPPD) with unilateral vestibular hypofunction (PPPD-UVH) subgroup and the UVH group

Variables	PPPD-UVH (n = 21) Mean ± SD	UVH (n = 10) Mean ± SD	<i>p</i>	<i>r</i>
UP-SVV, degree	2.05 ± 1.47	2.48 ± 1.33	0.287	0.19
Affected-HTPG	1.280 ± 0.314	1.030 ± 0.117	0.003**	0.52 ^b
Healthy-HTPG	1.225 ± 0.323	1.082 ± 0.155	0.217	0.23
HTPG laterality, %	6.51 ± 5.44	4.62 ± 3.54	0.519	0.12
CP, %	46.6 ± 26.1	71.6 ± 33.7	0.077	0.33 ^a
cVEMP (asymmetry ratio), %	34.9 ± 34.4	33.5 ± 29.5	0.790	0.05
oVEMP (asymmetry ratio), %	20.3 ± 23.5	42.0 ± 48.2	0.834	0.04
Foam ratio	2.23 ± 0.63	3.72 ± 2.17	0.075	0.34 ^a
Romberg ratio on foam	2.02 ± 0.67	2.40 ± 0.81	0.257	0.22

CP, canal paresis; cVEMP and oVEMP, cervical and ocular vestibular-evoked myogenic potentials; HTPG, head-tilt perception gain; SD, standard deviation; UP-SVV, upright subjective visual vertical.

^aValues indicate the magnitude of the effect size, medium.

^bValues indicate the magnitude of the effect size, large.

**Values indicate statistical significance, $p < 0.01$.

DISCUSSION

In patients with chronic dizziness, visual vertical-related parameters such as UP-SVV, mean HTPG, and HTPG laterality were in the normal range not only in the PPPD and PD groups but also in the UVH group (Table 1). However, the mean HTPG of patients in the PPPD group (1.203) and UP-SVV of patients in the UVH group (2.48) were close to the upper limit of the normal range (normal range: HTPG, 0.8–1.25; UP-SVV, <2.5°). This could be attributed to the presence of chronic disease stage in all patients, because of which the UP-SVV, which is affected by disease stages (18,19), had already been compensated. In contrast, CP, cVEMP, and oVEMP had not been compensated, but the values for patients in the UVH group were not in the normal range (Table 1). Since UP-SVV reflects the gross gravity sensing function at the level from the peripheral otolith organs to central vestibular circuits, unfixed peripheral otolith function, indicated by abnormal VEMPs, may

be compensated in the chronic stage of UVH by the central vestibular mechanisms, leading to normal UP-SVV.

The mean HTPG showed differences among groups (Table 1), and results of the post-hoc Dann–Bonferroni test revealed that the mean HTPG of patients in the PPPD group was significantly greater than that of patients in the UVH and PD groups (Fig. 2). In spite of normalizing the influence of vestibular dysfunction by comparing the results between the PPPD-UVH subgroup and the UVH group, the affected-HTPG was significantly greater in the PPPD-UVH subgroup than in the UVH group (Table 2). Similarly, the mean HTPG was higher in the PPPD-NVH subgroup than in the PD group, indicating that the differences in mean HTPG were apparent between patients with PPPD and without vestibular comorbidities and those with PD. Taken together, the mean HTPG of patients in the PPPD group was greater than that of patients in the UVH and PD groups, irrespective of the presence of vestibular comorbidities. Furthermore,

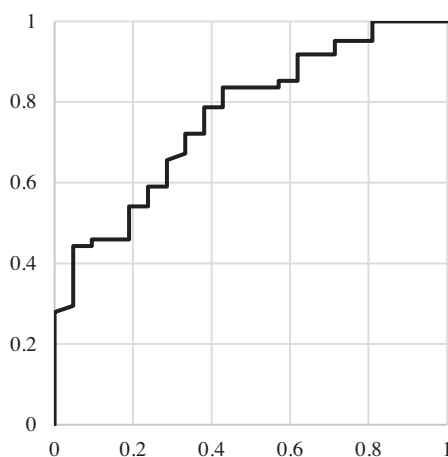
TABLE 3. Comparisons between the persistent postural-perceptual dizziness (PPPD) with no vestibular hypofunction (PPPD-NVH) subgroup and the psychogenic dizziness (PD) group

Variables	PPPD-NVH (n = 35) Mean ± SD	PD (n = 11) Mean ± SD	<i>p</i>	<i>r</i>
UP-SVV, degree	1.57 ± 1.49	1.55 ± 0.84	0.445	0.12
Mean HTPG	1.175 ± 0.178	1.030 ± 0.097	0.007**	0.39 ^a
HTPG laterality, %	3.73 ± 3.60	4.28 ± 3.47	0.629	0.07
CP, %	11.0 ± 18.1	7.91 ± 3.47	0.704	0.06
cVEMP (asymmetry ratio), %	22.5 ± 27.5	23.4 ± 28.6	0.912	0.02
oVEMP (asymmetry ratio), %	22.2 ± 28.6	23.1 ± 23.6	0.558	0.11
Foam ratio	2.06 ± 0.67	2.03 ± 0.61	0.979	0.01
Romberg ratio on foam	1.84 ± 0.42	1.91 ± 0.73	0.612	0.08

CP, canal paresis; cVEMP and oVEMP, cervical and ocular vestibular-evoked myogenic potentials; HTPG, head-tilt perception gain; SD, standard deviation; UP-SVV, upright subjective visual vertical.

^aValues indicate the magnitude of the effect size, medium.

**Values indicate statistical significance, $p < 0.01$.



AUC	95% CI	Youden index	Cut-off value	Sensitivity	Specificity
0.764	0.652 - 0.876	0.407	1.042	0.836	0.571
		0.395	1.202	0.443	0.952

Youden index: sensitivity+specificity-1

FIG. 3. The receiver operating characteristic (ROC) curve for the mean head-tilt perception gain (HTPG). The area under the curve (AUC) of the ROC curve was 0.764 (95% confidence interval [CI]: 0.652–0.876), and the mean HTPG of 1.042 and 1.202 had the best sensitivity (mean HTPG of 1.042: 83.6%; mean HTPG of 1.202: 44.3%) and specificity (mean HTPG of 1.042: 57.1%; mean HTPG of 1.202: 95.2%) for diagnosing persistent postural-perceptual dizziness.

HTPG laterality was within the normal range in patients with PPPD (Table 1). HTPG occurs on the side lateral to the side of the UP-SVV shift during vestibular asymmetry (20). All these findings suggest that the greater HTPG without laterality seen in PPPD may be a characteristic of PPPD, but not due to the presence of possible comorbid vestibular conditions or vestibular asymmetry; thus, HTPG can serve as a useful clinical tool for diagnosing PPPD in patients with chronic vestibular symptoms.

HTPG is highly dependent on the HTA; an underestimation could be a result of an HTA $> 60^\circ$ (A-effect), while an overestimation could be caused by an HTA $< 30^\circ$ (11). When the HTA is as low as 30° , as in the present study, HTPG is usually > 1 (E-effect). The E-effect leads to a hyper-perception of the head tilt, implying an overestimation of uprightness during the head tilt. HTPG is known to be greater while standing than sitting with the head upright and in elderly participants than in younger ones (15). Moreover, in patients with vestibular asymmetry, HTPG occurs on the side lateral to the side of the UP-SVV shift (20). These findings suggest that the greater perception of SVV gain during head tilt (E-effect) could be helpful in subsidizing postural instability while standing upright due to age and/or vestibular asymmetry, possibly by enhancing the righting reflex. However, prolonged E-effects following recovery from precipitating conditions in patients with PPPD could be harmful in maintaining spatial orientation, which would be easily disrupted by hypersensitivity to the head roll-tilt. Since Cleworth et al. (21) reported

that the psychological state such as height-induced postural threat significantly affects perceptions of body position, persistent hypervigilance in patients with PPPD may cause a hyper-perception of the head tilt. This could partly account for symptom exacerbation while standing upright in patients with PPPD.

Only the mean HTPG in the HT-SVV test but not the conventional UP-SVV showed abnormalities in patients with PPPD. The basic differences between UP-SVV and HT-SVV were the inputs to the somatosensory organs of the neck. The greater HTPG in patients with PPPD could be due to hypersensitivity to neck somatosensory stimulation. This assumption would explain the characteristics of patients with PPPD whose symptoms are exacerbated by active/passive movement that can be perceived by vestibular, visual, and accompanying somatosensory inputs (6).

The AUC of the ROC curves for discriminating between PPPD and chronic dizziness using mean HTPG was 0.764, showing moderate accuracy in the diagnosis of PPPD. The best two Youden indexes were obtained when the cut-off value was set at 1.042 or 1.202. Of these, 1.202 showed relatively low sensitivity (44.3%); however, the specificity was as high as 95.2%. The relatively low sensitivity means that the HT-SVV test is not a useful screening tool, and clinicians must actively include PPPD in their differential diagnosis lest they overlook it. However, a mean HTPG of 1.202 or higher could be considered highly specific for PPPD, and thus a very useful clinical confirmatory test for the diagnosis of PPPD.

As limitations, age and sex differed among disease groups. Due to the small sample size of each group, there was no statistical power to correct between group-comparisons for age and sex. Since HTPG is higher in elderly patients than in younger participants and in women than in men (15), group differences in age and sex might have affected the differences in HTPG among the disease groups. Statistical analysis regarding precipitants, comorbidities, and medications were not performed due to the small sample size. There still remain possibilities that these factors may have affected the results of this study.

In conclusion, while the PPPD group showed no significant abnormalities in the results of the conventional vestibular tests including VEMPs, posturography, and UP-SVV, high HTPG in the HT-SVV test, an excessive perception of head tilt, can be considered a specific marker for discriminating between PPPD and other chronic vestibular diseases. The mean HTPG of 1.202 or higher had a specificity as high as 95.2%; hence, it could be clinically useful in the diagnosis of PPPD.

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