ARTICLE

Distance Horizontal Fusional Facility (DFF): A Proposed New Diagnostic Test for Concussion Patients

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ABSTRACT

Purpose: To report the retrospectively-based, clinical findings in a newly-proposed distance vergence facility test for concussion diagnosis.

Methods: A new distance fusional facility (DFF) test for horizontal vergence (4 pd base-out/2 pd base-in) was assessed in three populations in the first author's optometric practice: (1) post-concussion, visually-symptomatic (n=52), (2) non-concussed, visually-symptomatic (n=18), and (3) non-concussed, visually-asymptomatic normal patients (n=21). Ages ranged from 9-29 years. The DFF values were also compared to the COVD-QOL scores and the near vergence facility values in the same three populations.

Results: The DFF scores were significantly lower and abnormal in the visually-symptomatic, post-concussion group as compared to the visually-normal group. There was a significant, negative correlation between the DFF values and the COVD-QOL scores, while there was a significant, positive correlation between the DFF values and the near vergence facility test values, in the concussed group.

Conclusions: The DFF test appears to be a useful adjunctive clinical tool in the diagnosis of concussion in children and young adults. Future testing should be performed in older adults, as well as in the clinical monitoring of concussion recovery.

INTRODUCTION

The area of 'concussion' is currently one of the dominant fields of investigation in contemporary medicine.[1] This keen interest is evidenced by formal discussions and research reports, and first-person accounts, of players in the National Football League[2] and other sports (e.g., hockey[3]) over the past decade, as well as those in college and high-school sports,[4] regarding their array of potential physical and psychological problems subsequent to a concussive-type of head injury.

A concussion can result in a number of neurological deficits including cognitive dysfunction, balance difficulties, and short-term memory deficits, to name a few.[5] More specifically, there can be a constellation of related visual problems, such as visually-based headaches, photosensitivity, oculomotor-based reading deficits, general eye tracking problems, and vergence dysfunctions.[5,6]

Given the above, there has been considerable effort on the part of vision care providers and related professionals (e.g., physiatrists, neurologists) to develop a profile of visual signs and symptoms in the concussed population,[5-8] as well as to ascertain possible therapeutic interventions.[5,6] In addition, there has been research directed to detect and identify both clinical and laboratory-based, visual system biomarkers for the presence of a concussion, such as the King-Devick test[9] and infrared pupillometry,[10,11] respectively.

There have only been two previous investigations of distance vergence facility.[12,13] The first was performed in normal, visually-asymptomatic (n=20) and visually-symptomatic (n=20) young adults.[12] They used a wide range of base-out and base-in flipper prism combinations, up to 9pd base-in (BI) and 18pd base-out (BO), and found the 3pd BI/12pd BO prism combination to be optimal in differentiating the symptomatic from the asymptomatic individual. However, they reported that the repeatability, which was assessed one month later in a subset (n=8) of the original asymptomatic control group of 20, was relatively low (r = 0.23). The diagnostic power of this test was assessed in a second study (n=30) of visually-symptomatic subjects. Of the 30 subjects, 18 failed distance and/or near vergence facility (60%), and 3 failed distance vergence facility only. Repeatability was not assessed.

With this in mind, the first author has informally observed that many post-concussion patients, at various stages in their injury, exhibited reduced horizontal, relative, dynamic facility vergence ranges at distance, which was the driving rationale for the study. While such a finding is common at near for both static (i.e., ranges) and dynamic (i.e., facility) vergence ability in this population,[14,15] there has been relatively little emphasis on *distance* horizontal, dynamic vergence capability. Thus, the primary purpose of the present retrospective study was to assess distance vergence dynamics in a sample of medically-documented, concussed individuals with related visual symptoms as compared to asymptomatic, visually normal, non-concussed individuals. A secondary purpose was to make this comparison in symptomatic patients without a history of concussion.

METHODS

The patients were examined in the practice of the first author, who personally tested all individuals, with the visually symptomatic concussed group all having a medical diagnosis of concussion. The comprehensive vision examination was the same in all, which encompassed the areas of refractive status, binocular/motility status, and ocular health status. Three categories of patients were tested and compared: (1) visually-symptomatic, visually-abnormal individuals (ages 9-25 years, mean 16.4 years, SEM = 0.5, n = 52) with a recent history (typically 1-8 months post-injury) of concussion; (2) visually-symptomatic, visually-abnormal individuals (ages 9-29 years, mean 16.6 years, SEM = 1.4, n = 18) without a history of concussion; and (3) visually-asymptomatic, visually-normal individuals without a history of concussion (ages 9-26 years, mean 16.9 years, SEM = 1.3, n = 21). All had 20/25 or better visual acuity with correction at both distance and near. None had strabismus.

Three clinical tests/metrics were used in the study. These included the College of Optometrists in Vision Development Quality of Life questionnaire (COVD-QOL), near horizontal vergence dynamic facility, and a distance horizontal vergence dynamic facility test recently developed by the first author

specifically for assessment in the concussed population.

1. COVD-QOL:[16] The College of Optometrists in Vision Development Quality of Life (COVD-QOL) questionnaire was administered to, and completed by, each patient. This has 30 questions related to various aspects of vision, such as blur, diplopia, reading problems, sports activities, visuomotor ability, attention, and time management. There are five response categories: never, seldom, occasionally, frequently, and always, for each question, with a score of 0 for 'never' and 4 for 'always'. A total score of greater than 20 is considered to be visually-symptomatic. The maximum total symptomatic score is 120.
2. Near horizontal vergence facility:[6] This was assessed as follows. First, the patient was given instructions for the test, followed by a short demonstration and brief practice. The instruction was to fuse the target as rapidly as possible. Then, the actual testing commenced. The target was comprised of a fine pen tip placed at 40cm along the midline, with full room illumination. The prism flipper consisted of 12 prism diopters (pd) base-out and 3 pd base-in prisms attached to a handle.[12] The doctor alternated the prism each time the patient regained fusion. The number of cycles was assessed over a 60 second period.
3. Distance horizontal, fusional vergence facility (DFF) (available at Bernell.com, Bernell-Tannen Flipper Test): This is a test recently developed by the first author. It is a horizontal prism flipper, dynamic fusional facility test for distance. Vergence was assessed as follows. First, the patient was given instructions for the test as in #2 above, followed by a short demonstration and brief practice. Then, the actual testing commenced. The target was comprised of a single 20/30, high contrast, Snellen letter placed at 17 feet away along the midline, with dim room illumination. The prism flipper consisted of 4 pd base-out and 2 pd base-in prisms attached to a handle. The doctor alternated the prism flipper each time the patient regained fusion. The number of cycles was assessed over a 60 second period. Based on preliminary testing, the first author found that using a small target, dim room illumination, and relatively low-powered prisms, resulted in the most provocative test/stimulus condition to evoke a consistently abnormal response in the concussed population.

The statistical analyses were as follows:This included either a one-way ANOVA, Pearson correlation, or t-test, depending on the test performed and comparative populations. A p-value of less than 0.05 was considered to be statistically significant.

RESULTS

The overall results are presented in Table 1. There were several significant findings.

With the one-way ANOVA, there was a significant main effect on the DFF test for the factor of clinical group [$F(2, 88) = 8.162$, $p = 0.001$]. The post-hoc test (Tukey's Honestly Significant Different Method) revealed that there was a significant difference between the visually-symptomatic, post-concussion group and the visually-normal, non-concussion group ($p < 0.001$). It was lower and abnormal in the former. It was not significantly different between the visually-symptomatic, post-concussion group and the visually-symptomatic, non-concussion group ($p > 0.05$).

Several correlations were performed.There was a significant, negative correlation between the DFF test and the COVD-QOL score ($r = -0.283$, $p = 0.007$), in the concussed group. However, here was no correlation ($p > 0.05$) between the COVD-QOL score and either age

at testing (r = 0.092, p = 0.385) or time since last concussion (r = -0.118, p = 0.404). There was a significant, positive correlation between the DFF test and the near vergence facility test (r = +0.402, p = 0.003) in the concussed group. Lastly, there was no correlation between time since last concussion and either distance vergence facility (r = -0.09, p = 0.52), or near vergence facility (r = -0.16, p =0.24).

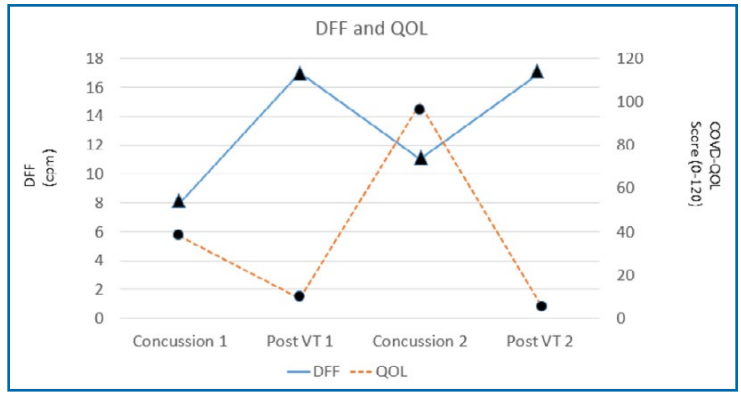

Figure 1

DISCUSSION

The DFF is a proposed new, simple, rapid, and inexpensive clinical test that may be assistive in an adjunctive capacity to differentiate the symptomatic, post-concussed patient from the asymptomatic, visually-normal, non-concussed patient, which was the primary purpose of the study. This would be especially important and informative in the diagnosis of concussion in those for whom the symptoms are vague and/or mild, or the related case history is poorly defined. Our secondary goal was to compare the DFF test values in concussed, visually-symptomatic patients to non-concussed visually-symptomatic individuals. No significant difference was found, although the DFF values were typically lower in the former group. This is not necessarily surprising, as it simply reflects a basic "vergence dysfunction" in both groups.

DFF could serve as a good baseline, pre-post concussion type of test, with the advantage of seemingly having good persistence after a concussion in the visually-symptomatic individual. That is, based on our tentative impressions, as long as the concussive symptoms are present, the score will likely be abnormal and thus be diagnostic. This test could be administered at the beginning of the season by the team coach or trainer, or team medical doctor, and then immediately re-administered at the sidelines if a concussion were suspected, or perhaps in the locker room where the visual test stimulus can be better controlled than in the active playing field.

DFF may also serve as a test that helps describe and quantify concussion recovery as it pertains to level of visual symptoms.This is shown in Figure 1 for a patient examined in the first author's optometric practice. This 16-year-old boy was a hockey player in his high school. He sustained his first concussion during a hockey game, which was medically documented. Upon presentation in the optometric practice 7 months later, he reported the symptoms of headaches, reduced reading ability, poor memory, photosensitivity, and behavioral changes with onset of the concussion. He also remarked that his school grades had sharply fallen. The optometric diagnosis was accommodative insufficiency, convergence insufficiency, and saccadic dysfunction. Based upon this, he was prescribed a 24-session program of basic vision therapy, 2 in-office sessions per week of 45 minutes each, with an emphasis on global oculomotor aspects.[6] He was also prescribed a BPI Omega tint (which has a blue-purplish hue) for his photosensitivity (http://www.brainpowerusa.com), and 0.5 pd base-in prisms (each eye) for near work. At completion of the therapy, all had normalized – he reported being "100%". Furthermore, he no longer required the near prismatic correction. Unfortunately, 3 months later, he sustained another concussion in a hockey game, with return of his initial symptoms. He was then prescribed a 12 session program of vision therapy; at completion, all again had normalized. After the initial concussion, the DFF score was 8, which is abnormal; following successful vision rehabilitation, it increased to 17, which is normal, and which reflected a

greater than 200% improvement. However, the DFF value returned close to the initial baseline concussion value after the new concussion, now being 11; following the second shorter period of vision rehabilitation, it again normalized to 17. Thus, the potential for this test to be used in a recovery capacity is promising. Lastly, his COVD-QOL scores followed a similar pattern at these four assessment periods: 38, 9, 99, and 7, respectively.

Table 1: DFF and COVD–QOL scores for the three diagnostic groups

Diagnostic Group	DFF (cpm)	COVD-QOL
NCVA	16.90 ± 1.32	7.43 ± 1.22
NCVS	13.50 ± 0.97	36.50 ± 2.97
PCVS	11.44 ± 0.54	30.09 ± 2.61

Symbols: NCVA = non-concussion, visually-asymptomatic
NCVS = non-concussion, visually-symptomatic
PCVS = post-concussion, visually-symptomatic
cpm = cycles per minute. Presented is the mean + 1 standard error of the mean (SEM).

The question of test-retest repeatability of the distance vergence facility test is important to address. In one of the earlier studies,[12] it was only assessed in a small subset (n=8) of the original (n=20) visually-asymptomatic, control group and found to be low. However, the relatively large prism values used in the earlier two studies may have fatigued the subjects leading to greater variability and relatively poor repeatability. It was not formally assessed in the present study, but observations by the first author suggest "good" repeatability in the few concussed patients tested/retested. Furthermore, the relatively small SEM values found (Table 1) are consistent with the above notion. Clearly, test-retest repeatability should be assessed formally in both the concussed and non-concussed, visually-symptomatic populations to ascertain better its clinical utility.

There are several possible future directions. First, the present, positive, retrospective study should be followed by a larger and more detailed prospective investigation, with its greater power and population generality, and with inclusion of older adults as well as repeatability assessment. This larger sample would also allow for the possibility of patient subsets to be formulated with different diagnostic and prognostic signatures. Second, other visual symptom surveys should be used in conjunction with the new DFF test to test for generality of the effect. Third, the DFF findings should be compared with the horizontal, static vergence ranges at both distance and near for possible correlation and insight. Lastly, baseline pre-post concussion data should be obtained to assess the likelihood of the DFF test providing critical recovery information.

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