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Test-Retest Reliability and Responsiveness of Gaze Stability and Dynamic Visual Acuity in High School and College Football Players

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TEST-RETEST RELIABILITY AND RESPONSIVENESS OF GAZE STABILITY
AND DYNAMIC VISUAL ACUITY IN HIGH SCHOOL AND
COLLEGE FOOTBALL PLAYERS

By

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A doctoral project submitted in partial fulfillment
of the requirements for the

Doctor of Physical Therapy

Department of Physical Therapy

School of Allied Health Sciences

The Graduate College

University of Nevada, Las Vegas

May 2013

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THE GRADUATE COLLEGE

We recommend the doctoral project prepared under our supervision by

Denise Kaufman
Mallory Puckett
Mitchell Smith

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Test-Retest Reliability and Responsiveness of Gaze Stability and Dynamic Visual Acuity
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ABSTRACT

Objectives: The purpose of this study was to establish reliability and responsiveness of the active dynamic visual acuity test (DVAT) at speeds of 150 to 200 degrees per second (deg/sec) and the gaze stabilization test (GST) in high school and college football players.

Design: Reliability design

Setting, Participants, Main Outcome Measures: A total of 50 high school and college football athletes completed vestibulo-ocular reflex testing using the DVAT and GST in the yaw (horizontal) and pitch (vertical) planes on two separate occasions within 14 days.

Results: Test-retest reliability for the DVAT was good in yaw, Intraclass Correlation Coefficient (ICC) (3,3) = 0.770 (95% confidence interval (CI): 0.595 to 0.861), and moderate to good in pitch, ICC (3,3) = 0.725 (95% CI: 0.515 to 0.844). Minimal detectable change (MDC) at the 95% confidence level was 0.16 logMAR for yaw and 0.21 logMAR for pitch. Test-retest reliability for the GST was moderate in yaw, ICC (3,3) = 0.634 (95% CI: 0.355 to 0.792), and poor in pitch, ICC (3,3) = 0.411 (95% CI: -0.037 to 0.666). MDC was 73.4 deg/sec for yaw and 81.2 deg/sec for pitch.

Conclusions: Our results provide evidence that the DVAT is reliable at relatively high speeds in high school and college football athletes in both yaw and pitch. GST speeds were considerably higher than previously reported in the literature, but reliability of this tool for this population is only poor to moderate according to our results. From a clinical perspective, DVAT can be reliably used in the assessment of vestibular concussion for high school and college football athletes; however, GST requires further evaluation of its reliability and clinical use.

Keywords: concussion, vestibulo-ocular reflex, reliability, responsiveness

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INTRODUCTION

Concussions have become a prevalent topic and pressing issue in modern sports, particularly in the sport of American football. Recently, it was estimated that 135,901 sport-related concussions occurred during one high school academic year and collegiate concussion rates are even higher (Gessel, Fields, Collins, Dick, & Comstock, 2007). An 11 year prospective study on the incidence of concussions in 12 high school sports found that rates have an average yearly increase of 15.5% (Lincoln, Caswell, Almquist, Dunn, Norris, & Hinton, 2011). Research also shows that football-related concussive injuries appear to have the highest incidence rate per athletic exposure of all high school and collegiate sports (Gessel et al., 2007; Lincoln et al., 2011). Unfortunately, with each of these concussive injuries, an athlete has increased susceptibility to an additional concussive event, as well as greater likelihood of the next concussion being more severe with a more protracted recovery (Collins, Lovell, Iverson, Cantu, Maroon, & Field, 2002; Guskiewicz, Weaver, Padua, & Garrett, 2000; Guskiewicz et al., 2003; Iverson, Gaetz, Lovell, & Collins 2004). The occurrence of concussions could actually be an even greater problem than the literature indicates due to probable underreporting by players, in addition to a general misunderstanding of the broad spectrum of symptoms that can signify a concussion (McCrea, Hammeke, Olsen, Leo, & Guskiewicz 2004; Mulligan, Boland, & Payette 2012).

There is an array of symptoms associated with concussions. The most common are headache, disorientation, and dizziness as reported by collegiate athletes on the Concussion Symptom Survey (LaBotz, Martin, Kimura, Hetzler, & Nichols, 2005). This 14-item survey assesses severity of head injury based on prevalence and frequency of

self-reported symptoms (LaBotz et al., 2005). Although the cerebral components are often recognized in recovery from these symptoms, the effects that a concussive incident has on an athlete's vestibular system are also deserving of attention. Vestibular rehabilitation post-concussion has been shown to be successful in patients with dizziness, gait deficits, and balance issues that did not resolve by simply resting (Alsalaheen et al., 2010). Kisilevski et al. (2001) demonstrate that vestibular symptoms existed in most subjects tested after minor head trauma, with 13% of the subjects having purely vestibular symptoms after injury. Because some concussions may be primarily vestibular or have a significant vestibular element, more research attention on the vestibular system after concussion is certainly warranted.

One of the ways to test the vestibular system post-concussion is to assess the function of the vestibule-ocular reflex (VOR). The VOR is the body's mechanism for fixating the eyes on an object while the head is moving. This reflex is mediated by the vestibular system and ocular motor nuclei. Leigh & Brandt (1993) suggest that the VOR is best tested during high-velocity, linear and angular movements. Two functional tests used in VOR assessment are active dynamic visual acuity testing (DVAT) and gaze stabilization testing (GST) (Goebel, Tungsiripat, Sinks, & Carmody, 2007; Herdman, Tusa, Blatt, Suzuki, Venuto, & Roberts, 1998). These clinical tests aid in examining the VOR while the head is moving actively at high velocities, which are required for both functional and athletic tasks (Crane & Demer, 1997). This implies that DVAT and GST may be appropriate tests for populations such as athletes that use their VOR during challenging sports performance. In addition, DVAT and GST may aid in differentiating vestibular deficits, indicating the side of a lesion in unilateral vestibular dysfunction, and

gauging progress during vestibular rehabilitation (Goebel et al., 2007; Herdman et al., 1998; Herdman, Schubert, Das, & Tusa, 2003; Roberts, Gans, Johnson, & Chisolm, 2006).

In a sport such as football, where competitive edge hinges on optimal athletic performance, a functioning VOR and vestibular system is fundamentally important. When the vestibular system has been damaged from a concussive event, the sequelae may negatively impact athletic performance, especially if an athlete is not given optimal time to recover and post-injury care. Collins et al. (2002) recommended that athletes be symptom-free before returning to competition in their sport, yet Guskiewicz et al. (2000) estimate a third of high school and college football players who experience a concussion return to competition within 13 minutes of the episode. This quick return to competition is troubling when one considers that five days post-concussion deficits in verbal memory, reaction time, visual processing, postural stability, and balance have been noted (Cavassin, Stearne & Elbin, 2008; Guskiewicz, Ross, & Marshall, 2001). Trying to juggle both subjective and objective measures, which is the convention, and having to account for the many different types of lingering effects creates a difficult situation for trainers and coaches when attempting to make an informed decision about when to allow an athlete to return to play (Piland, Ferrara, Macciocchi, Broglio, & Gould, 2010).

DVAT and GST may be helpful objective assessment tools in recognizing vestibular dysfunction and determining vestibular involvement in the assessment of concussions, including return to play decisions. However, there is no published data that establishes reliability of the DVAT and GST at the head speeds necessary for competitive play in high school and college football. Researchers have indicated the need for more

reliable tests to recognize and assess all symptoms of concussion and, more specifically, have mentioned testing tools for assessing VOR and vestibular function in highly trained individuals during challenging tasks (Gotshall & Hoffer, 2010; Mulligan et al., 2012; Ward, Mohammed, Brach, Studenski, Whitney, & Furman, 2010a). DVAT at speeds of 60-120 deg/sec and GST have been shown to be reliable tools for assessing vestibular function and measuring rehabilitation progress in those with vestibular deficits or concussion (Goebel et al., 2007; Gottshall, Drake, Gray, McDonald, & Hoffer, 2003; Gottshall & Hoffer, 2010; Mohammad, Whitney, Marchetti, Sparto, Ward, & Furman, 2011; Ward, Mohammad, Whitney, Marchetti, & Furman, 2010b). However, all previous studies, to our knowledge, have only been conducted on general adult or soldier populations, and they have not performed DVAT at speeds of 150-200 deg/sec. These faster speeds would tax the vestibular system more than slower speeds, and may be more indicative of speeds required for most athletes.

Determining the reliability of the DVAT and GST at higher velocities of head movement for football athletes is an important foundational step in the assessment of concussions with suspected vestibular involvement. Therefore, the primary purpose of this study was to establish test-retest reliability of DVAT at speeds ranging from 150-200 deg/sec and GST in high school and college football players. Responsiveness (i.e., minimal detectable change (MDC)) of the DVAT and GST will also be determined to aid in return-to-play decision making. A secondary purpose was to determine if a history of concussion contributed to long term changes in DVAT and GST results.

METHODS

Sample

Fifty subjects (age = 18.3, SD = 2.3) consented under UNLV Institutional Review Board approval. Subjects included 20 male high school football players (n = 20; age = 15.9, SD = 0.85) and 30 male Division 1 college football players (n = 30; age = 19.9, SD = 1.25). Subjects were excluded if they reported a current neck injury or neck pain, a current concussion or head injury, a current inner ear or upper respiratory tract infection, nystagmus, Meniere's disease, or any other diagnosed vestibular disorder.

Instrumentation

DVAT and GST were completed using the InVision System by Neurocom (NeuroCom, Clackamas, Oregon, USA) that includes the static visual acuity (SVA) test and the perception time test (PTT) as pre-testing measures. Essential instruments for this system include the computer program, a computer screen, and the motion sensor head piece (Figure 1).

Procedures

All participants (n=50) performed the testing protocol twice within two weeks, but not within the same day (Figure 2). The time between tests and time of day tested varied depending upon the availability of players' schedules. Players were tested during the offseason while participating in strength, conditioning, and skills practices without padding. All subjects completed an intake form regarding their history of concussions, motion sickness, migraines, and long-term use of amino glycosides in addition to reviewing exclusion factors. Subjects were notified to wear any necessary corrective lenses during testing (Goebel et al., 2007). Ten subjects wore contact lenses during the

tests, but no subjects wore glasses. Subjects were tested in a room with ambient lighting and solid white walls to minimize visual distractions. They were seated 10 feet away from a computer screen adjusted to eye-level. Subjects were given a brief practice period immediately prior to their initial DVAT and GST in order to orient them to the visual cues of the Invision system and the testing protocols (Herdman, Schubert, & Tusa, 2001). Subjects were to demonstrate the ability to maintain adequate active cervical range of motion and head velocities as required before beginning the tests. If subjects became dizzy or nauseous with any testing, they were given water and a brief rest period until symptoms subsided. This occurred with 2 subjects during testing, but these subjects were able to complete both tests.

SVA was measured at the beginning of each subject's test in order to determine how well the subject could see with the head stationary and establish a basis for comparison during head movement. During SVA test, the optotype E would appear in the center of the computer screen for one second. The subject would then state the position of the optotype (i.e., up, down, left, or right). SVA values are derived from the Snellen fraction and converted to a value referred to as the logMAR (Table 1). The PTT measures the minimum amount of time that an optotype can appear on the screen with the subject correctly reporting its positioning. It establishes a visual perceptual baseline for later dynamic testing. In order to prevent a corrective saccade, subjects were excluded if their PTT surpassed 80 milliseconds. This exclusion is consistent with other research protocols (Leigh & Brandt, 1993; Ward et al., 2010a).

DVAT measures the difference between SVA and DVA associated with yaw (horizontal plane) and pitch (vertical plane) head motions.⁸ In the yaw plane, subjects

rotated their heads from side to side (approximately 20 degrees in each direction) at an average achieved velocity (AAV) of at least 150 deg/sec but not more than 200 deg/sec. Once the velocity and proper range of motion were maintained for three consecutive head movements, the optotype appeared and the subject was asked to report its orientation. The same methods were used for the pitch plane except the subjects flexed and extended the neck.

GST measures the maximum velocity in which an individual can maintain their visual acuity or identify the optotype accurately when it appears on the screen while performing a yaw or pitch head motion. GST was conducted identically to the DVAT, with the exception that the inVision system generated varying target velocities to determine the maximum velocity in which the subject could correctly identify the optotype. The optotype size remained constant at 0.2 logMAR above the measured SVA. The average of the subject's 3 highest achieved velocities with correct responses to the optotype orientation is used as the reported maximum head velocity.

Statistical Analysis

All statistics were produced using SPSS (version 19, SPSS Inc., Chicago, IL). In line with previous research analyzing results from DVAT and GST, left and right DVAT logMARs or GST maximum velocities were averaged to make one yaw value for each test. The same was done for up and down logMARs or velocities, and their averages equal to the pitch values (Ward et al., 2010b). These averages and other descriptive statistics for each of the tests were grouped and analyzed according to three groups: all subjects (n=50), high school subjects (n=20), and college subjects (n=30).

Test-retest reliability was determined between the two different test day values of both the yaw and pitch planes for DVAT and GST. The intraclass correlation coefficient (ICC) two-way mixed model with 95% confidence intervals (95% CI) was used for the reliability analysis. A paired samples t-test was performed to determine if there was a difference between the first test and the second test; this was done to determine if a learning effect had occurred. The MDC was calculated using the formula: $MDC_{95} = \text{standard error of measurement (SEM)} \times 1.96 \times \sqrt{2}$. The SEM is the standard deviation (SD) of the measurement errors of multiple trials and is calculated with the formula: $SEM = SD\sqrt{(1-ICC)}$.

Independent samples t-tests were used to determine if there was any difference between those with a history of concussions (n=18) and those without a history of concussions (n=32) for the first tests of DVAT and GST. Independent samples t-tests were also used to determine if there were any differences between skilled (n=31) and unskilled (n=19) player positions and between high school (n=20) and college athletes (n=30). Skilled positions were defined as quarterbacks, receivers, running backs, defensive backs/safeties, linebackers, and tight ends. Unskilled positions were defined as offensive and defensive linemen.

RESULTS

Overall means and SDs for all tests and subjects were -0.247 logMAR for SVA and 22.4 milliseconds for the PTT. The mean and SD of GST maximum head velocity and DVAT visual loss logMAR scores are shown in Table 2 for each of the tests and planes. Test-retest reliability for the DVAT was good in the yaw plane, ICC (3,3) = 0.770 (95% CI: 0.595 to 0.861), and moderate to good in the pitch plane, ICC (3,3) =

0.725 (95% CI: 0.515 to 0.844). Test-retest reliability for the GST was moderate in the yaw plane, ICC (3,3) = 0.634 (95% CI: 0.355 to 0.792), and poor in the pitch plane, ICC (3,3) = 0.411 (95% CI: -0.037 to 0.666). ICC values were similar for each separate group when analyzed in high school and college subgroups (Table 2). Results for each MDC₉₅ are shown in Table 2 as well.

A statistically significant difference was observed between tests 1 and 2 for both planes of the DVAT and in the yaw plane of the GST. LogMAR scores improved for DVAT in the yaw plane from test 1 (mean = -0.0383, SD = 0.1157) to test 2 (mean = -0.0712, SD = 0.1277), $t(49) = 2.207$, $p = 0.032$. LogMAR scores also improved for DVAT in the pitch plane from test 1 (mean = -0.0262, SD = 0.1398) to test 2 (mean = -0.0133, SD = 0.1458), $t(49) = 2.105$, $p = 0.04$. AAVs improved for GST in the yaw plane from test 1 (mean = 184.6, SD = 38.9) to test 2 (mean = 208.9, SD = 48.6), $t(49) = 3.782$, $p < 0.005$. However, there was no statistically significant difference for GST in the pitch plane between test 1 (mean = 162.5, SD = 33.9) and test 2 (mean = 175.7, SD = 42.5), $t(49) = -1.994$, $p = 0.052$.

There were no differences observed between those with a reported history of concussions and those without in either plane for DVAT and GST, $ps \geq 0.062$. In addition, there were no differences between high school and college athletes for GST and DVAT ($ps \geq 0.234$), except there was for GST in the pitch plane with college athletes having achieved 21.3 deg/sec greater AAV than high school athletes, $p = 0.028$. There were differences between DVAT and GST in the yaw planes between skilled and unskilled players, $p = 0.014$ and $p = 0.012$, respectively. The skilled players performed better in both tests with an average of 28 deg/sec higher GST AAVs and 0.081 logMAR

lower DVAT scores. There were no differences noted between skilled and unskilled players in the pitch planes for either DVAT or GST, $p_s \geq 0.320$.

DISCUSSION

Our results provide evidence that the DVAT is reliable at relatively high speeds (150 to 200 deg/sec) in high school and college football athletes in both the yaw and pitch planes. This is the first study to report reliability of this test in a younger athletic population with high velocities. Average GST achieved velocities were higher than previously reported in the literature^{6,20,27} (Figure 3), which suggests that football athletes are capable of maintaining visual acuity at considerably higher speeds as compared to previous studies using the general public (Goebel et al., 2007; Mohammad et al., 2011; Ward et al., 2010b). However, the results for GST were only moderately reliable. Since the subjects in the study were all from an asymptomatic athletic population (i.e., no current vestibular symptoms) the variability in their performance was relatively low; a more heterogeneous sample would have likely produced higher reliability coefficients.

These reliability results are consistent with much of the literature which shows that the DVAT and GST have moderate to good test-retest reliability (Figures 4 and 5). As seen in the figures, Ward et al. (2010b) established GST as moderately reliable for both within and between testing sessions for 20 younger adults (age = 25.2, SD = 3.2) and 20 older adults (age = 76.3, SD = 5.3). In their study, DVAT was moderately reliable within sessions, but they reported poor to fair reliability between sessions (Ward et al., 2010b). However, Mohammad et al. (2011) report much higher ICC values for DVAT test-retest reliability than that of GST showing mostly good reliability for DVAT and poor reliability for GST. Mohammad et al. (2011) tested a population of 29 patients

of ages 16 to 78 with vestibular disease. These two studies performed the DVAT at speeds of 60-120 degrees per second. An earlier study done by Herdman et al. (1998) performed DVAT in the yaw plane at higher speeds of 120-180 degrees per second for a population of adults of ages 19 to 87 with and without vestibular dysfunction and found good reliability with a similar computerized DVAT system. Taken together, our results and those of the aforementioned studies suggest that the DVAT is sufficiently reliable to be used in a clinical or research setting, and the GST is to be more cautiously utilized.

The difference in reliability displayed by Ward et al. (2010) could be due to testing order as the GST was performed before the DVAT in their study, and the DVAT was performed before the GST in our study. Fatigue by the person being tested, either mentally or physically, could potentially reflect a testing effect which logically could have increased the variability and, hence, decreased the reliability of the test that measured last. Our testing order stayed consistent throughout and no rest breaks were given to accommodate for this fatigue, which may have led to our results of lower reliability for the GST. However, Mohammad et al. (2011) randomized the order of these two tests, and the DVAT was found to be the more reliable test. Therefore, decreased reliability of the GST may have been due to additional reasons to the possibility of subject fatigue. The GST may be a more difficult test to perform consistently since it challenges the subject by regularly increasing or decreasing speeds based on performance, whereas the speeds for head movement in the DVAT are constant. Because of the changing speeds with the GST, it requires more attention from the subject and the administrator than the DVAT. The GST seemed more difficult for the test administrators to give efficient cues for those being tested to achieve the system's requested varying

velocities. The GST computer program additionally caused some problems for test administrators as it resulted in more errors that required repeat testing due to an unreported score. Thus, unreported scores which could affect reliability were more common in the GST than in the DVAT. The algorithm for determining maximum head velocity by averaging a subject's three highest scores may also warrant further evaluation and revision to improve the test's reliability.

From a clinical perspective, our results show that DVAT can be a reliable tool used to assess high school and college football athletes and may offer some value in the recognition and evaluation of vestibular concussions; however, GST may not currently be appropriate since the reliability was marginal in our study. Clinicians may also benefit from DVAT responsiveness values. These tools could aid in recognizing vestibular deficits associated with a head injury and in making educated, return to play decisions after concussions for football players. To make educated decisions for players with vestibular symptoms, DVAT should be considered as a baseline tool to compare concussed athletes against themselves. In other words, comparing DVAT scores after suspecting or while recovering from concussion to pre-season baseline scores would aid in clinical decision making. This proposed pre-season testing is in line with current concussion research and other concussion assessment tools, such as the Sensory Organization Test for postural stability (Guskiewicz et al., 2001; Mulligan et al., 2012). The MDC_{95} offers value in that one can be 95% confident that a DVAT logMAR score decrease of greater than 0.16 in the yaw plane and 0.21 in the pitch plane was beyond measurement error and perhaps suggestive of concussive vestibulopathy. Decision

makers could use this or other thresholds determined through future studies to help make objective, return to play decisions for athletes with vestibular concussive symptoms.

It should be noted that our results comparing first tests to second tests suggest a likely learning effect for both the GST and DVAT. Previous reliability studies have not shown or mentioned significant improvements from test 1 to 2 (Mohammad et al., 2011; Ward et al., 2010b); however, this should be considered when taking baseline measures. Multiple initial tests may decrease a learning effect and increase the usefulness and accuracy of comparing someone's pre-concussion scores with post-concussion scores. Future studies using several measurement periods is warranted to better determine the extent of this learning effect.

Our secondary analysis suggests that there are no differences in DVAT and GST scores between those players with a history of concussion and those without. Although Slobounov, Cao, Sebastianelli, Slobounov, & Newell (2010) found some significant residual postural deficits when they tested 12 athletes 30 days after a concussive event, our study found no significant vestibular changes, as assessed by the DVAT and GST, in those with a history of concussion. Unlike their study, our subjects were not compared against any pre-concussion baseline tests, but were compared against their peers without a known concussion history which may account for finding no residual deficits. We also did not gather or analyze specific information on concussion history such as when events occurred, symptoms experienced at the time, or severity. However, all subjects were excluded if they reported current concussive symptoms as mentioned in our exclusion criteria. In addition, all testing occurred during the off season; therefore, it is likely that those with a history of concussion may not have had residual symptoms. In light of this,

our results should be interpreted with caution and future studies should be conducted to assess long-term changes in vestibular function with concussions.

Additionally, we analyzed results to determine if there were differences between skilled versus unskilled players and college versus high school athletes. It was thought that the greater coordinative requirements accompanying those playing skilled positions or those who are competing at the college level may logically have had higher GST and DVAT scores than those playing unskilled positions or those competing at the high school level. This notion is consistent with the literature that demonstrates that high-level athletes in both motorsport and water polo have been shown to have superior dynamic visual acuity when compared to non-elite athlete populations (Quevedo-Junyent, Aznar-Casanova, Merindano-Encina, & Sole-Forto, 2011; Schneiders, Sullivan, Rathbone, Thayer Wallis, & Wilson, 2010). Our results suggest that skilled position players may perform slightly better for tests in the yaw plane than unskilled position players. This may be due to the nature of the positions because skilled positions such as quarterback, running back, and linebacker require frequent scanning of the field for teammates and opposing players, while offensive and defensive linemen are usually more focused on dealing with the opposing player directly in front of them. The scanning required more frequently by skilled positions may challenge and subsequently strengthen the VOR in the horizontal plane more so than for those playing unskilled positions who may scan the field less frequently. There may have been no difference in the pitch plane between skilled and unskilled positions because all football players are not required to scan vertically as often as horizontal scanning. Our results also suggest college athletes had higher GST AAVs in the pitch plane than high school athletes, but GST pitch results

were found to have poor reliability earlier in this study. Therefore, this result cannot be interpreted as authentic from our study, and in general, our data suggest DVAT and GST scores are similar for college and high school football players. However, since these results were only a secondary part of our study and analysis, they should also be considered with some caution and mainly aid in the encouraging of further research on the topic.

Limitations

A possible limitation for this study includes the use of multiple testing environments for different players. High school players were tested in the same room at a local high school; however, college players were subject to slightly varying light or surroundings during testing based on the availability of two separate testing facilities. The time of day tested and time between tests 1 and 2 also varied slightly from subject to subject due to the convenience of their schedules. This lack of control to slight variations in setting could have limited the reliability of our results. Another limitation is that in some instances, testing elicited symptoms that could have affected performance. Nine subjects in our study reported minor symptoms of headache or dizziness during either their first or second testing sessions. Two subjects asked for and were given a 3-5 minute break, but no participant ever requested to terminate testing. There was no universal rest period between the DVAT and GST in our methods to accommodate for these potential symptoms or possible fatigue, which may have contributed to decreased GST reliability results. In addition, it has been noted that DVAT and GST scores improved over the two tests suggesting a possible learning effect, which can be seen as a limitation in the study design. This effect should be taken into consideration when testing and using the test as a baseline measurement.

CONCLUSION

The results of this study provide evidence that the DVAT can be a reliable tool for testing high school and college football athletes at higher velocities. GST velocities demonstrate football players' ability to maintain VOR at higher velocities since their speeds were considerably higher than previously reported for other populations. However, reliability of this tool for this population was only poor to moderate. Clinicians may reliably use the DVAT in the assessment of vestibular concussion for high school and college football players, but GST may require evaluation of its current procedures for improvement and further research to assess its reliability. Utilizing the responsiveness of the DVAT to reference players' test results may also be of value to clinicians in making educated return-to-play decisions for athletes with vestibular involvement in concussions.

Figure 1. Instrumentation for the DVAT and GST using the InVision System by Neurocom.



Figure 2. Schema of study design.

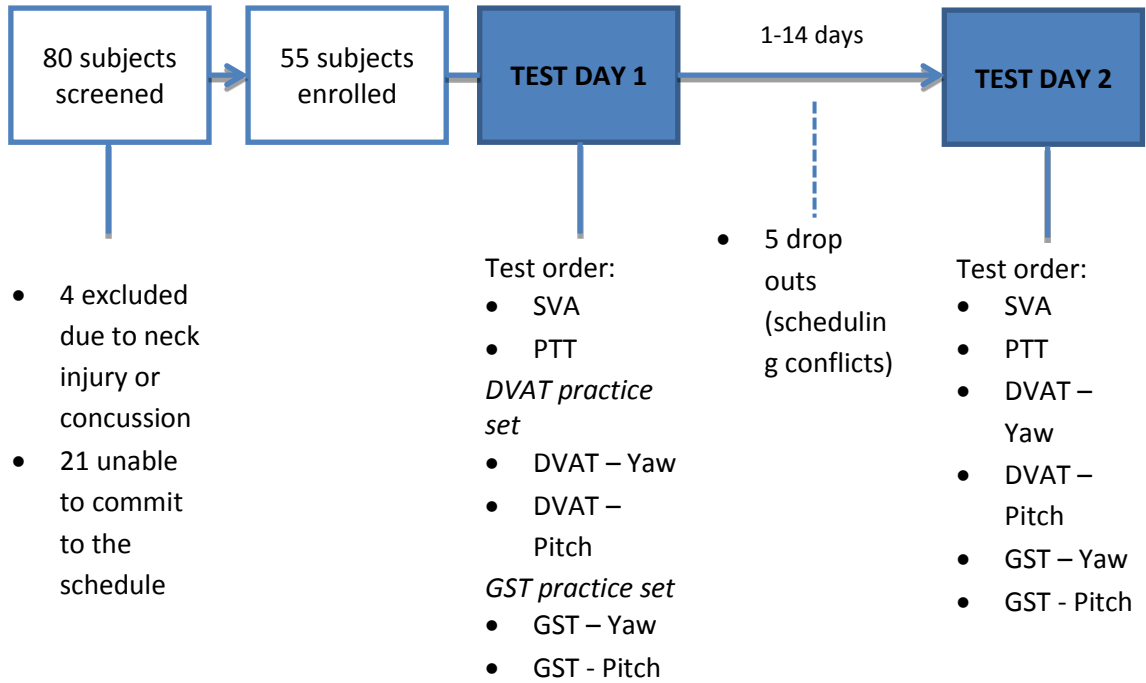


Figure 3. Means with standard deviations for the GST AAV for the present study, the Mohammed et al. (2011) study, and the Ward et al. (2010) study. Means and standard deviations were taken from the average of the two reliability measurements.

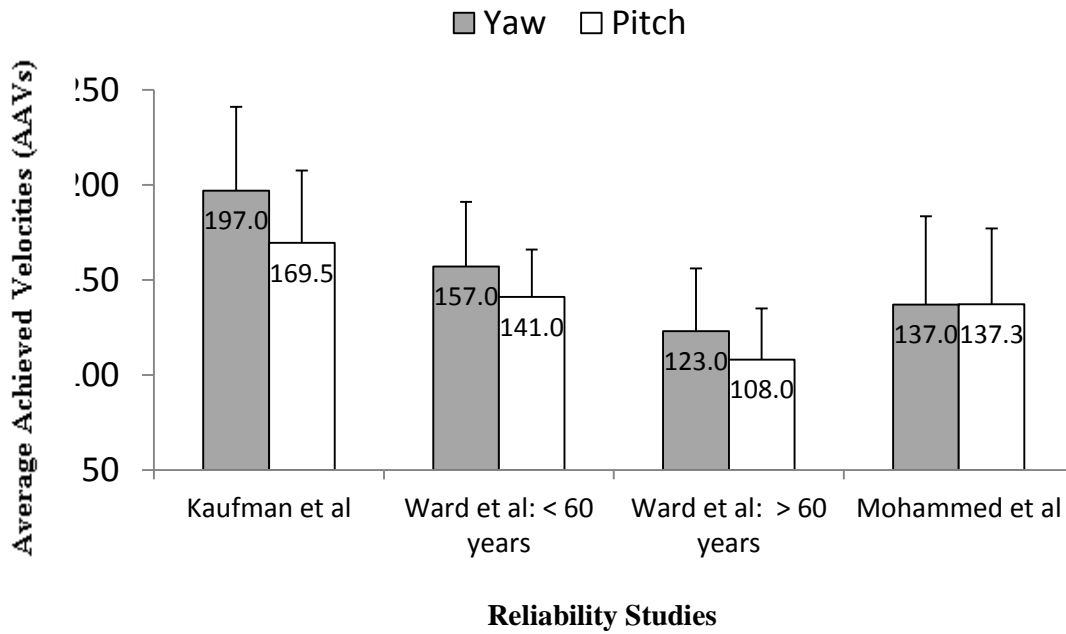
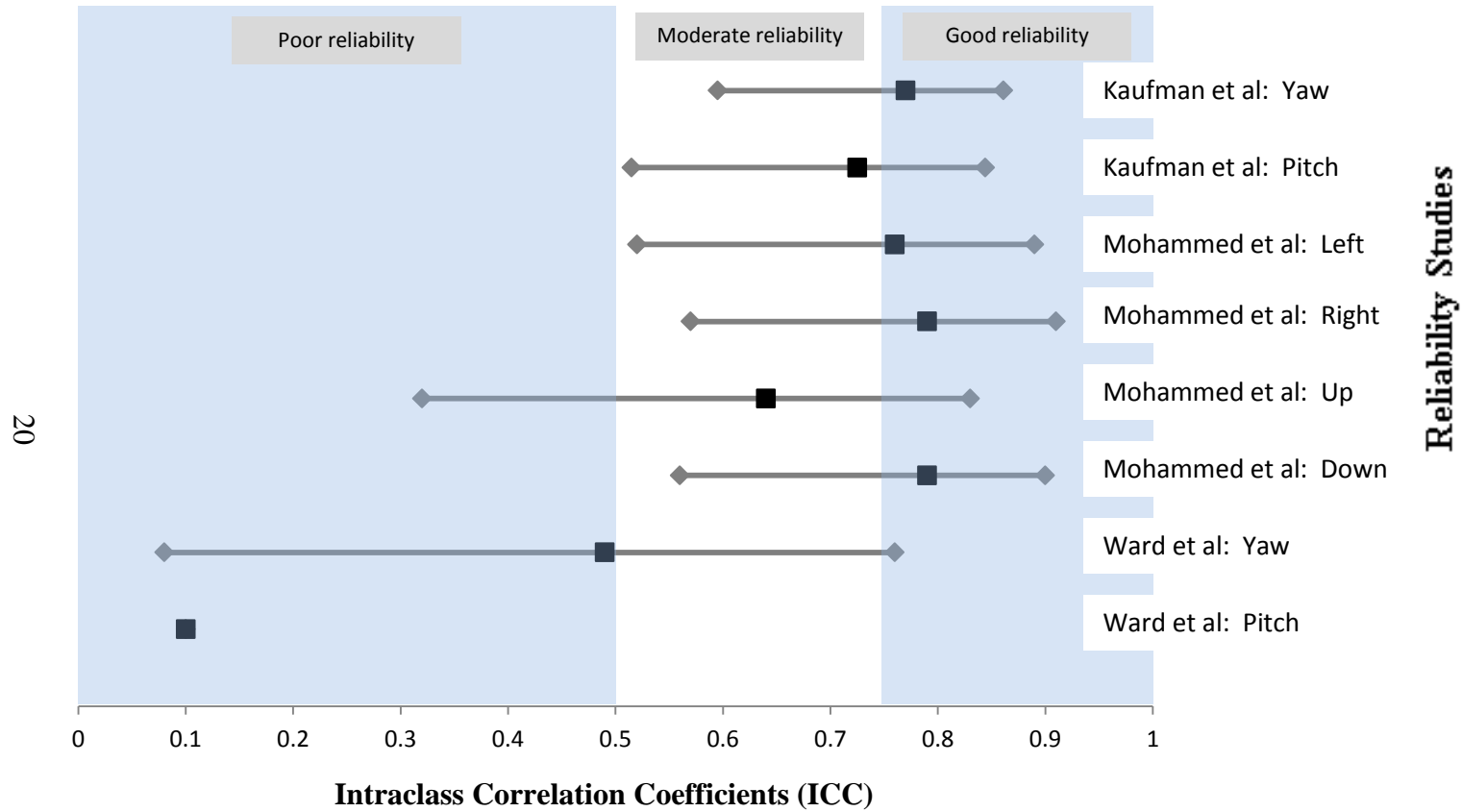
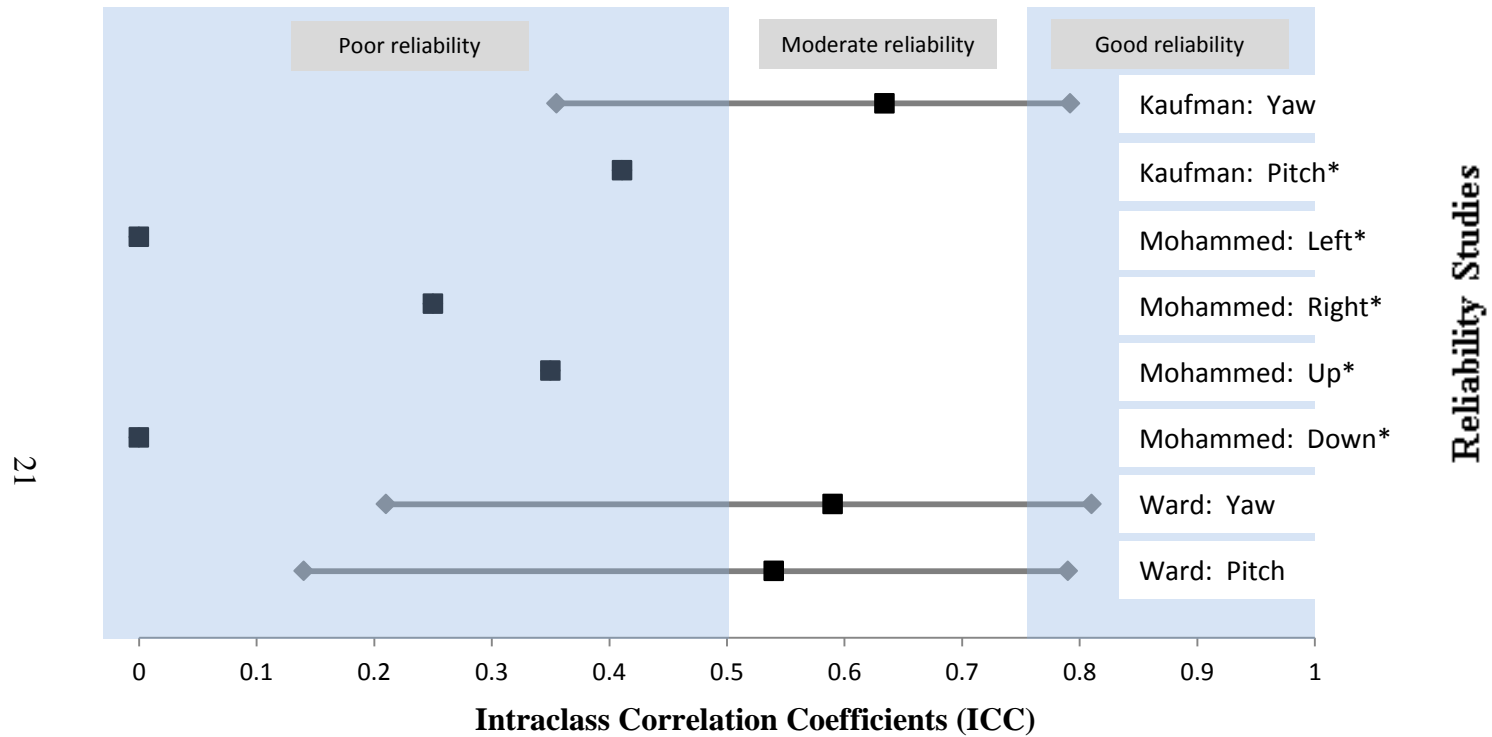


Figure 4. DVAT mean reliability values with 95% confidence intervals for the present study, the Mohammed et al. (2011) study, and the Ward et al. (2010) study.



* $p > 0.05$, Analysis of Variance F-test against $ICC = 0$.

Figure 5. GST mean reliability values with 95% confidence intervals for the present study, the Mohammed et al. (2011) study, and the Ward et al. (2010) study.



*ICC value not statistically different from 0 ($\alpha=0.05$).

Table 1. Conversion of standard visual acuity to LogMar scores from Neurocom International, Inc. inVision System Clinical Integration Manual.

Visual Acuity (Feet)	LogMAR (rounded)
20/200	+1.00
20/160	+0.90
20/125	+0.80
20/100	+0.70
20/80	+0.60
20/65	+0.50
20/50	+0.40
20/30	+0.20
20/25	+0.10
20/20	+0.00
20/13	-0.10

Table 2: Mean (SD) Gaze Stabilization Test (GST) and Dynamic Visual Acuity Test (DVAT) results for two testing sessions: Test 1 and test 2 performed within 2 week period but not on the same day.

Group	Test		Test 1 mean (SD)	Test 2 mean (SD)	ICC (3,3)	95% CI	MDC ₉₅
All subjects (n=50)	DVAT (logMAR)	Yaw	-.04(.12)	-.07(.13)	.770	.595 to .861	.16
		Pitch	.03(.14)	-.01(.15)	.725	.515 to .844	.21
	GST (deg/sec)	Yaw	185(39)	209(49)	.634	.355 to .792	73.41
		Pitch	163(34)	176(42)	.411	-.037 to .666	81.21
High School (n=20)	DVAT (logMAR)	Yaw	-.03(.09)	-.05(.11)	.719	.291 to .889	.15
		Pitch	.06(.14)	.03(.15)	.756	.383 to .903	.20
	GST (deg/sec)	Yaw	181(40)	201(44)	.748	.364 to .900	58.64
		Pitch	150(32)	168(36)	.528	-.194 to .813	129.14
University (n=30)	DVAT (logMAR)	Yaw	-.04(.13)	-.09(.14)	.786	.551 to .898	.17
		Pitch	.01(.14)	-.04(.14)	.676	.320 to .846	.22
	GST (deg/sec)	Yaw	187(39)	214(51)	.553	.060 to .787	83.39
		Pitch	171(33)	181(46)	.275	-.522 to .655	93.29

APPENDIX

Combined Sections Meeting 2013 Acceptance Letter:

Dear Dr. Merrill Landers,

This message is in reference to your poster presentation for the APTA Combined Sections Meeting 2013 in San Diego, California, from January 21 - 24:

TITLE: "Test-retest reliability and responsiveness of gaze stability and dynamic visual acuity in high school and college football players"

AUTHORS: Denise Kaufman(1); Mallory Puckett(1); Mitch Smith(1); Merrill Landers(1)

PRESENTER: Dr. Merrill Landers

FINAL ID NUMBER: 2171

The Poster Presenter Information document with your schedule, onsite check-in policies and formatting information is now available at www.apta.org/CSM/posterpresenter.

Your poster was accepted for:

SECTION: Neurology: Vestibular SIG

DATE/TIME OF PRESENTATION: See document at www.apta.org/csm/posterpresenter/

POSTER NUMBER: Your Final ID Number above is your poster number.

If you cannot present your poster, please notify Dr. Carole Tucker (caroletucker@comcast.net) as soon as possible to optimize the space for other poster presentations.

Thank you for participating in CSM 2013. We look forward to seeing you in San Diego. If you have questions concerning your actual poster presentation (scheduling, formatting), please feel free to contact Dr. Carole Tucker at caroletucker@comcast.net.

Mary Lynn Billitteri

APTA Professional Development

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Denise Kaufman

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Albuquerque, NM 87106

denise.kaufman13@yahoo.com

New Mexico Physical Therapy license: Pending

Education

- **Doctorate of Physical Therapy**
 - University of Nevada, Las Vegas; May 2013
 - **Bachelor of Science in Exercise Science**
 - University of New Mexico, 2009
 - Magnum Cum laude
 - Dean's List of the University of New Mexico 2005-2009
-

Experience

- ***HealthSouth Valley of the Sun Rehabilitation Hospital*** (Glendale, AZ)
 - Clinical Internship; January-April 2013
 - Managed full case load of patients with a variety of diagnoses to include orthopedic fractures and joint replacements, neurological conditions both acute and chronic and rehabilitation after traumatic injury. Focused therapy to address activity limitations and impairments that hindered the individuals level of mobility and independence.
- ***Scripps Mercy Hospital*** (San Diego, CA)
 - Clinical Internship; October-December 2012
 - Carried full patient load with 75% evaluations and 25% patient treatments and wound care. Provided examination and discharge recommendations for patients on a variety of floors including general medical, orthopedic, trauma and status post bariatric surgery. Evaluated wound and patient, created plan of care, and applied wound vac negative pressure system for wound progression and healing. Engaged in sharp debridement and dressing changes in the outpatient wound clinic.
- ***Advanced Physical Therapy*** (St George, UT)
 - Clinical Internship; July-September 2012
 - High concentration of outpatient orthopedic. Patient care was delivered in a clinic, aquatic and rural off site setting. Provided care for individuals with acute and chronic injuries, musculoskeletal imbalances as well as rehabilitation following joint replacement.
- ***Brian Werner Institute of Balance and Dizziness***, (Henderson, NV)
 - Clinical Internship; June-July 2011
 - Evaluated and treated patients with a variety of vestibular, balance and neurological conditions; Handled 70% of full caseload with supervision by end of affiliation.
- ***New Heart Cardiac Rehabilitation***, (Albuquerque, NM)
 - Exercise specialist in Phase II Cardiac Rehabilitation; Jan.–May 2010, August–Dec. 2009
 - Provided daily care of monitoring patients EKG, blood pressure, heart rate and oxygen saturation levels while they participated in personalized exercise and health programs of endurance, muscular strength and flexibility.
- ***Presbyterian Healthplex***, (Albuquerque, NM)
 - Outpatient Physical Therapy Volunteer Internship; January- April 2009
 - Under supervision of a PT, lead prescribed exercise programs and provided care to patients with neurologic dysfunction.
 - Worked with the geriatric population to improve balance and strengthening.
 - Completed initial health questionnaires and assessments for new patients.

Research Experience

- Test-retest reliability and responsiveness of gaze stability and dynamic visual acuity in high school and college football players
- Student investigator, Group mentored research project, April 2011- Present
Computerized Dynamic Posturography System Neurocom with Invision OS
Dynamic Visual Acuity and Gaze Stabilization Testing
Research Poster Presentation at APTA Combined Section Meeting, San Diego, CA

Professional Membership/Certifications

- American Physical Therapy Association Member since June 2010
 - New Mexico Chapter
 - Research Section Member
- Healthcare Provider CPR and AED Certification since 2011 (AHA Expires April 2013)

Continuing Education

- Combined Sections Meeting – APTA: San Diego, CA January 2013
 - Presenter in the Vestibular Poster Presentations
- Combined Sections Meeting – APTA; New Orleans, LA February 2011
- Nevada Chapter Meetings; June 2010 – June 2012

Recognition and Awards

- MANA Scholarship Award; August 2010
- UNLV Kitty Rodman Scholarship; Spring 2012

Hobbies and Interests

- Outdoor enthusiast that includes a variety of activities such as hunting white tail and mule deer, lake and stream fishing, camping, backpacking, and hiking to explore the surrounding area.
- Participant in an assortment of 5K charity runs to include Run for the Zoo supporting NM BioPark Society, Santa Run for Opportunity Village, Color Run to support Banner Health and the Special Olympics, Turkey Trot for YMCA, Urban Race to raise ALS awareness and medical volunteer at the 2012 Susan G. Komen 3-day race in San Diego, CA.

Mallory Puckett

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mallorypuckett@yahoo.com

Washington PT license: currently processing

EDUCATION

Doctorate of Physical Therapy

- University of Nevada, Las Vegas, to be completed May 2013

Bachelor of Science in Biology

- Washington State University, Presidential Honor Roll, May 2009

WORK EXPERIENCE

Summerlin Hospital, Las Vegas, NV

January 2013-April 2013

- Inpatient rehabilitation student internship
- Evaluated and treated patients with a wide variety of diagnoses including cerebrovascular accident, fracture and post-surgical orthopedic conditions, amputation, spinal cord injury, osteoarthritis, and traumatic brain injury
- Provided equipment training and adaptation for patients including application of standard orthotics
- Conducted wound care treatment including enzymatic, autolytic and sharp debridement techniques
- Participated in weekly interdisciplinary team conferences where patient's progress, goals, plan, and case management were discussed
- Performed weekly re-evaluations and conducted team management including direction and supervision of two physical therapy assistants

Kootenai Medical Center, Coeur D'Alene, ID

October 2012-December 2012

- Acute care physical therapy student internship on transitional intensive care unit, medical and surgical floors
- Established and implemented plan of care through established goals and desired functional outcomes
- Provided quality patient care through effective communication with all members of the healthcare team
- Performed daily examinations assessing cognition, assistive devices, community reintegration, motor function, joint integrity, muscle performance, sensory integration and aerobic capacity

Oasis Physical Therapy, Pasco, WA

July 2012-October 2012

- Outpatient physical therapy and aquatic therapy student internship
- Evaluation, examination and treatment of patients with various musculoskeletal, neurological, and cardiovascular impairments
- Formation and implementation of aquatic therapy interventions
- Assisted in implementation of community wellness seminars

Apex Physical Therapy, Cheney, WA

June 2011-July 2011

- Outpatient orthopedic care and women's health student internship
- Evaluated and treated patients with a wide variety of orthopedic conditions utilizing treatment techniques including muscle reeducation, progressive resistive exercises, muscle energy techniques, electrotherapeutic modalities and soft tissue mobilization
- Examined and treated patients with numerous women's health-related conditions, with a focus on incontinence, dyspareunia, interstitial cystitis, and pelvic congestion

RESEARCH EXPERIENCE

University of Nevada, Las Vegas Researcher

- Designed and implemented a study examining the responsiveness of gaze stability and visual acuity in high school and college football players
- Poster presentation at Combined Sections Meeting, San Diego, CA in 2013

SKILLS

Experience and fluency in the following computer systems:

- Statistical Analysis Software: SPSS
- Software Packages: Meditech, VHI, Microsoft Office suite

PROFESSIONAL MEMBERSHIPS/CERTIFICATIONS

- American Physical Therapy Association member since 2010
- Nevada Physical Therapy Association member from 2010-2012
- Physical Therapy Association of Washington member since 2012
- American Heart Association CPR and AED certified

MITCHELL J. SMITH

EDUCATION

Doctorate of Physical Therapy

June 2010 - May 2013

University of Nevada, Las Vegas; Las Vegas, NV

GPA: 3.7

Bachelor of Science, Exercise Science (Minor: Korean)

Aug. 2004 - April 2010

Brigham Young University; Provo, UT

GPA: 3.7

CLINICAL / WORK EXPERIENCE

Student Physical Therapist Intern

Cononus Healthcare - Mirabella Portland Facility, Portland, OR Jan. 2013 - April 2013

-Evaluated and treated a wide variety of predominantly geriatric patients in a skilled nursing setting

ProActive Orthopedic & Sports Physical Therapy, Oregon City, OR Oct. 2012 - Dec. 2012

-Examined, assessed and developed care plans for outpatients with mostly orthopedic conditions

Mountain View Hospital, Las Vegas, NV

July 2012 - Sept. 2012

-Performed evaluation, assessment, and intervention for patients in the acute hospital setting

VA Southern Nevada – East Clinic, Las Vegas, NV

June 2011 - July 2011

-Treated veterans with orthopedic and neurological issues in outpatient and home health settings

Graduate Assistant

University of Nevada, Las Vegas Department of Physical Therapy June 2011 - May 2012

-Assisted professors with department tasks and UNLV PT program development / promotion

Physical Therapy Aide / Technician

Spine, Orthopedic, & Sports Physical Therapy Clinic, Provo, UT

Nov. 2007 - April 2010

S.P.O.R.T.S. Physical Therapy, Las Vegas, NV

Jan. 2005 - April 2005

-Over 2000 hours of experience helping outpatient PT clinics to run smoothly and efficiently

PROFESSIONAL DEVELOPMENT

American Physical Therapy Association (APTA) Member

June 2010- Present

-Attended Combined Sections Meeting in Jan. 2013 and occasional “continuing education” courses

Mentored Research Project, UNLV DPT Department

Feb. 2011- Present

-Worked with HS and college football teams for a reliability study on vestibular concussion testing

- Assisted in constructing the study design, collecting data from subjects, and authoring the article
- Presented a poster pertaining to our research at Combined Sections Meeting 2013 for the APTA

AWARDS / CERTIFICATIONS

- **Passed** National Physical Therapy Examination (**NPTE**) for licensure as PT, taken 4/30/13
- Selected by faculty to receive 1 of 4 **graduate assistantships** for our department during 2011-12
- Received UNLV PT department chosen **scholarship** for 2011-2012 academic year
- Officially rated “Advanced Low” speaker of **Korean** (2009)

PERSONAL BACKGROUND

My career interests include home health physical therapy, geriatrics, CVA rehabilitation, balance training, chronic pain, prevention, wellness, long-term health maintenance, and Tai Chi as therapeutic exercise.

In addition to my passions in physical therapy, I also enjoy basketball, golf, biking, hiking, reading, nutrition, singing, song-writing, and serving in the community. From May 2005 – May 2007, I served a voluntary service mission for my church in the southeastern regions of South Korea.