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Research Article

Reliability Comparisons of Cervical Active Range of Motion Measuring Methods: Universal Goniometer versus Virtual Reality

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Abstract

The purpose of this research study is to compare the reliability of measuring active cervical range of motion performed with the universal goniometer with an FDA approved XRHealth virtual reality computer program and the Oculus Rift.

Methods: The design of the study is a single-blinded randomized controlled study. A sample size of 40 adults was recruited via email, posters, and person to person recruitment. The sample was comprised of males and females, ages 20 to 72-year-old. Equipment included a large universal goniometer with 12-inch arms and a covered full circle plastic body, oculus rift with a computer, VR Health System, chair with arms and a gait belt to control for trunk movements. All four investigators underwent a training session in the measurement of cervical range of motion utilizing a universal goniometer. Each participant was measured with each tool twice.

Results: Virtual reality demonstrated a statistically significant difference from the standard goniometer methods at a 99% confidence level (p=0.01). Both tools (goniometer and virtual reality) were found to have good to excellent inter-rater reliability.

Conclusion: This study suggests a virtual reality method can be used as a reliable clinical tool in comparison with the universal goniometric cervical active range of motion measurement. Recommendations for future studies should be focused on establishing the validity of virtual reality as an assessment tool using a larger sample size with a wide age range and those who have current cervical discomfort or are experiencing functional limitations in cervical ranges of motion.

Keywords: Virtual reality; Goniometry; Cervical ranges of motions; Examination

Introduction

There is an increasing array of technologies being utilized in healthcare ranging from adaptive wearable technology, to augmented reality, and even virtual reality. More importantly, there is an expanding use of technology in clinical rehabilitative applications and the pedagogy of future physical and occupational therapy professionals. Wearable technology and virtual reality (VR) are becoming more affordable, providing more objective patient information for clinical assessment while offering improved guidance of various therapeutic interventions. References comparing the application and measurement potential of virtual reality with the universal goniometer (UG), the gold standard, were extremely limited and failed to include standardized protocols [1-3]. Therefore, this research study sought to compare the reliability of measuring active cervical range of motions with the standard universal goniometer with those taken with an Oculus Rift and an approved FDA program from XRHealth.

The reliable use of the universal goniometer is important to clinicians since it assists in the comparison of effectiveness in therapeutic interventions and assesses patient progress during rehabilitative interventions.1 Active range of motion (AROM) testing is also important for impairment testing, assisting in formulating a diagnosis, and designing plans of care. The normal ranges for cervical range of motion with a universal goniometer include 40 degrees of flexion, 50 degrees of extension, 22 degrees of lateral flexion, and approximately 50 degrees of rotation [1].

Goniometric measuring poses some important clinical limitations, one of which, the goniometer does not mimic functional movements but motions in standard anatomical planes. For example, in the application of universal goniometry, a physical therapist would instruct a patient to complete the maximum attempt of movement to achieve full, pain-free range of motion in forward cervical flexion or rotation. However, in everyday life, cervical motion is an automatic and subconscious response to the external environment, moving in diagonal planes as opposed to instructions for only a set of sagittal, frontal, or axial planes for the neck [2].

Mumammad Nazim Farooq et al. conducted a double-blind study comparing the intra-rater and inter-rater reliability between two qualified physiotherapists for cervical active range of motion using a universal goniometer. The blinded physiotherapists measurements

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were recorded by a third physical therapist to eliminate the potential for bias. The cervical range of motion of 19 participants without an underlying cervical pathology, ranging from 20-24 years of age, were measured while in a seated position with their back straight and secured by a strap to the chair [2]. The purpose of this method was to reduce errors caused by additional trunk movement or postural compensations. There were two different sessions for measuring cervical range of motion, with one week separating the sessions. The results of the data analysis showed strong correlation values for inter-rater and intra-rater reliability within sessions and between sessions. These results are consistent with the findings of multiple previous studies using similar in methods with similar high to very-high values for both intra and inter-reliability [2-5]. A question remaining is, "Are there any current technologies that would have the same reliable capabilities for measuring cervical ranges of motions other than a universal goniometer"?

Virtual reality and motion detection capabilities have the potential ability to provide an assessment of dynamic cervical motion in a more interactive environment that can be comparable with real world routines. Also, virtual reality may provide the additional facet of extrinsic motivation. Motivation is defined by Mei et al. as an internal state or condition that activates guides, maintains or directs behaviors [6]. Virtual reality provides a situated learning environment that engages the participant while providing continuous and varied external feedback. This study by Mei et al. discussed the features of virtual reality that included immersion, interaction, imagination, and real-time interactivity that combined afforded participants broad range effective engagement experiences.6 The authors, using a Cronbach α Coefficient Value, determined the reliability of learning motivation using virtual reality showed a high coefficient value of 0.79 [6]. The study also found that situated learning contributed 18.9% to the participant's level of motivation [6]. Based on previous literature, it was hypothesized that motivation can be a powerful component in achieving these high results.

The potential applications of virtual reality can include both outpatient and inpatient clinical setting that could extend to remote interventions for the community or homecare setting in coordination with current Telehealth initiatives. Only one study was found to specifically address cervical range of motion reliability and validity using virtual reality. A study by Sarig-Bahat et al. investigated thirty asymptomatic cervical participants that were assessed using both conventional goniometer and virtual reality methods. The purpose of this study was to assess both inter and intra-rater repeatability. Results showed that intra and inter-rater reliability was practical for both the virtual reality and the conventional goniometer methods. More importantly, there was better repeatability when utilizing the virtual reality method [2].

As the nation's healthcare system expands the use of technology, virtual reality presents a more engaging patient experience and intervention for dynamic functional movement by manipulating their simulated reality transitioning to a more functional reality [6,7]. Lastly, the adaptation of new technologies as part of education, the benefits of virtual reality studies may provide a new pedagogy for teaching and better preparation of future healthcare professionals. The proposed question is, "To what degree is the reliability of Oculus Rift - XRHealth virtual reality methods compared with the standard goniometry measurements for measuring active cervical range of motion"?

Methods

The study design was a single-blinded randomized controlled study. A sample size of 40 adults was recruited via email, posters, and person to person recruitment. The age range was 20 to 72-year-old males and females. Inclusion criteria required willing participants to be free of known current cervical pathologies. Participants were excluded if they stated they had a history of cervical dysfunction, surgery, or trauma. To estimate the precision of inferences, a power calculation indicated a sample size of 30 subjects would be an adequate sample size. However, a targeted sample size of 40 was chosen to balance the interactions between each of the four raters. The goal was to have approximately 10 subjects for each paired group of raters with one being blinded to the actual goniometer and virtual reality measurements to avoid the potential for bias and to assess inter-rater reliability. Each participant was tested a total of four times, twice on the virtual reality and twice with the universal goniometer. Each rater performed one virtual reality session and one goniometer session to measure cervical motions in six directions. All participants were given written information regarding the purpose and nature of the study. An informed consent form was signed by each subject prior to participating in the study.

Measurement Procedure

The four investigators were randomly assigned numbers from one to four such that each were identified as Investigator/Rater 1, Investigator/Rater 2, Investigator/Rater 3, and Investigator/Rater 4, and then randomly divided into two rotating pairs. For both methods (universal goniometer and virtual reality), one of the investigators for each tested subject was responsible for measuring the cervical range of motion of the subject but was blinded to the actual numerical values. The second investigator recorded the values on a sheet of paper (Figure 1). Each subject entered the room with two investigators/raters to initially review the informed consent form before signing and to listen to the prepared instructions. The subject would be instructed to sit comfortably in the chair with their feet flat on the floor. A gait belt would be used around the subject's chest to secure the back of the chair to control for any potential compensatory trunk movements. The "measuring" investigator/rater would measure cervical ranges of motions in the same sequence of motions involving flexion, extension, right and left side bending, and right and left rotation for both the blinded universal goniometer and virtual reality methods. The "measuring" investigator/rater would present the goniometer with the results of each measured motion to the "recording" investigator/rater. The "recording" investigator/rater would record all values on the form in Appendix A.

Goniometry procedure

In order to standardize procedures, all four investigators underwent a training session in the measurement cervical range of motion utilizing a universal goniometer, including bony landmarks and verbal cueing. All investigators were doctoral physical therapy students. A large universal goniometer with 12-inch arms a full plastic circular body with 360 degrees for potential motion measurement

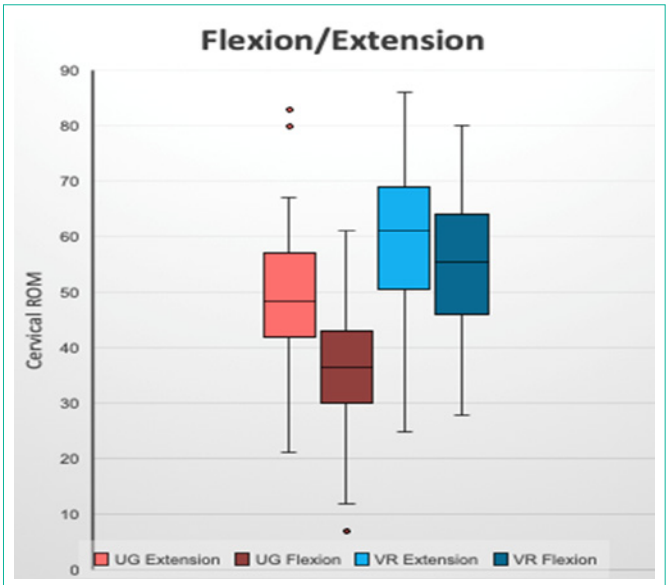

Figure 1: Comparison of cervical ranges of motions of all subjects using the universal goniometer and virtual reality methods with the bar representing the mean of each method range of motion in flexion and extension (UG: Universal Goniometer; VR: Virtual Reality.

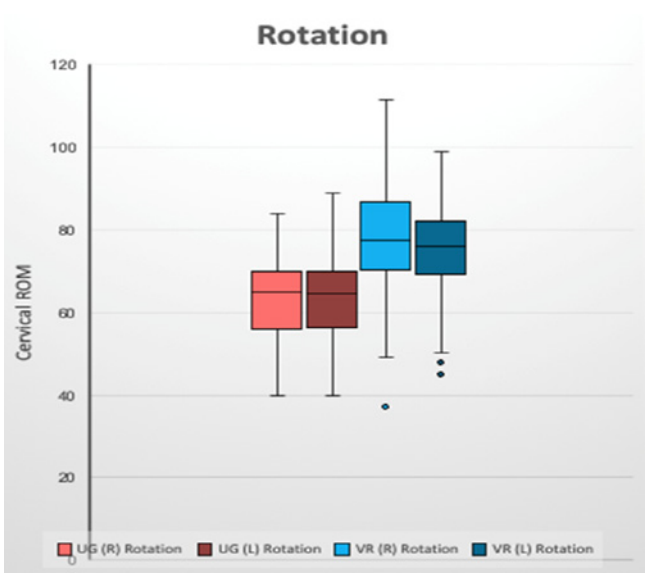

Figure 2: Comparison of cervical ranges of motions of all subjects using the universal goniometer and virtual reality methods with the bar representing the mean of each method range of motion in right and left rotation.

had one side blackout and out of view from the evaluating investing rater. The other side was used by the recording rater to capture the measured degrees of motion. Each rater that performed the cervical motions in flexion, extension, right rotation, left rotation, right lateral flexion, and left lateral flexion was blinded to the goniometer numbers and the resulting cervical measurements.

Virtual reality procedure

The Oculus Rift head gear with a computer storing the operating system for the XR Health System program for data collection was set up and calibrated prior to the subject's arrival. Instructions to the

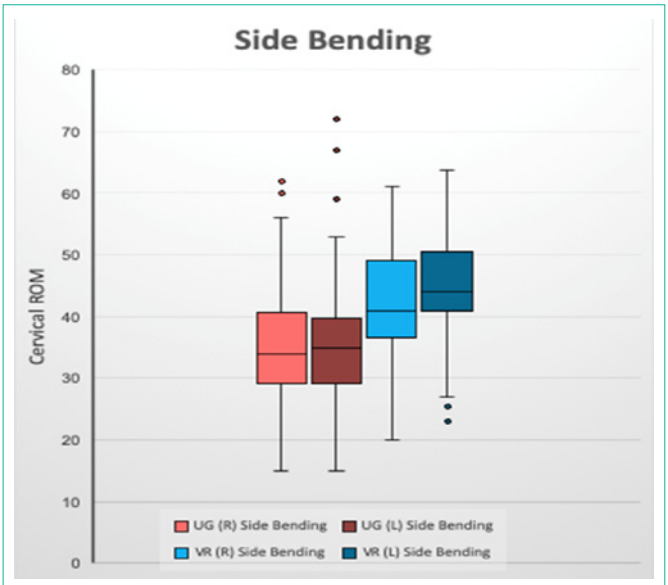

Figure 3: Comparison of cervical ranges of motions of all subjects using the universal goniometer and virtual reality methods range of motion right and left side bending.

subject would be read from a prewritten script to ensure consistency for all raters and expectations of the subjects. The headset would be secured and adjusted as needed to each subject prior to the virtual reality session. The subject would listen and follow the instructions from an avatar in the virtual reality program displayed on the Oculus. Rift headset. The virtual reality program instructed the subject through the same sequence of cervical ranges of motions as performed with the universal goniometer. The "recording" investigator would take the recorded values keeping the "measuring" investigator blinded to the results. The paired raters would then switch roles with the same subject and the methods were repeated to assess inter-rater reliability. After the completion of the measurements, a survey would be given to the subject to assess their perceptions of each measuring method and record their preference between the two assessment tools identified as Appendix B. The final data analysis will be performed independently by two American International College psychology program faculties and a public health faculty member. Inter-rater reliability was assessed using the Pearson correlation.

Results

The overall results of the data analysis demonstrated that the virtual reality method was able to capture greater cervical ranges of motions for all three directions by 19.8%, 35.9%, and 20.2% for cervical rotation, flexion/extension, and lateral flexion respectively. Statistical significance when compared with average cervical ranges of motions was assessed by calculating the p-value revealed the virtual reality method demonstrating a statistically significant difference from the universal goniometer method with confidence levels at 99% (P=0.01). The results indicate good to excellent reliability for the virtual reality method when compared with the universal goniometer method. The Pearson correlational values of 0.727, 0.515, and 0.824 for the virtual reality in comparison with the universal goniometer method for the same motions of 0.723, 0.242, and 0.748 respectively.

There was a subjective survey given after both measurement

Table 1: Comparison of correlational values with comparing methods of measuring cervical ranges of motion between using the goniometer and the virtual reality methods between the different student rater/investigators. The low correlational value in goniometer rotation for student raters 2 and 3 may be due to the low sample size for that group or inter-rater reliability.

Inter-rater Correlation Values	Goniometer		Virtual Reality	
	Rotation	Side Bending	Rotation	Side Bending
Rater 1 + 2 (n=11)	0.79	0.71	0.73	0.83
Rater 2 + 3 (n=4)	0.06	0.58	0.46	0.67
Rater 1 + 3 (n=11)	0.71	0.81	0.84	0.91
Rater 2 + 4 (n=7)	0.63	0.5	0.81	0.8
Average	0.55	0.65	0.71	0.8

methods were completed and interaction with raters revealed that 75% of all tested subjects preferred being measured using the virtual reality methods over the goniometer methods. In addition, the subjects stated it was easier to keep the cervical movements in the plane of motion being tested. The most common comment noted was the way the virtual reality appeared to incentivize the subject to achieve their maximal potential for cervical motions. The three resulting figures below provide a more visual representation of the data and the data comparison of each cervical motion and studied method.

With each subject being measured using the goniometer and virtual reality twice, once by one rater and then again by the other rater, the format permitted the conditions to measure inter-rater reliability between the goniometer and virtual reality methods (Figure 2, 3 and Table 1).

Discussion

This study was performed to examine the inter-rater reliability and statistical significance using virtual reality compared with the standard goniometer. The results demonstrated good to excellent inter-rater reliability and were found to be statistically significant for virtual reality. Virtual reality consistently recorded greater AROM, which may be a possible secondary effect of the motivational component of the virtual reality experience. Given the relatively small sample sizes, both virtual reality and universal goniometer measurements were consistent by each rater and between raters.

This study found similar results of virtual reality for inter-rater reliability when comparing active cervical range of motion reliability between raters among asymptomatic patients as a prior study by Bahat, Sprecher, Sela, and Tre leaven [2]. The authors found the results of universal goniometer for inter-rater reliability like a study by Whitecroft, Masoud, Amirfeyz, et al. comparing active cervical range of motion reliability between raters on asymptomatic patients.3 However, in the study by Bahat et al, an external electromagnetic tracking system (Fastrak) was used while this study used XRHealth software. XRHealth software developed for physical therapy clinics is a simulator providing verbal and external cues for which range of motion to be performed. External cues contained within the software reflected an increasing row of dots that would increase as the subject continued their motions providing feedback and motivation to subjects that may have incentivized them. The time for set up averaged a mere 30 second difference between administration of virtual reality and universal goniometer.

Virtual reality and universal goniometer can both be used for assessment; however, based on surveys provided, virtual reality demonstrated more positive engagement during the measurements. Additionally, virtual reality appeared to have influenced compliance and participation. This could have been because the time taken to perform both methods was similar, and there was a greater motivational factor with the virtual reality. The survey found the virtual reality method incentivized them to move through greater range of motion, gave instructions with continuous visual cues, and provided positive reinforcement upon completion of all cervical motions.

Currently, virtual reality is being researched to be used for assessment and possibilities of intervention. Possible applications of virtual reality are using the tool as therapeutic exercise or therapeutic activity. As it collects the patient's ROM during the assessment portion, the physical therapist can easily recognize the decreased ROM. The program may then use the ROM data to focus an activity in the deficit area to address the decrease in ROM and apply cogent interventions as a practical application of virtual reality. In a prior study using VR for shoulder ROM assessment compared with the standard goniometer, it was found that shoulder flexion goniometry revealed moderate to good Intraclass correlation coefficients (ICC) compared with moderate to excellent for the virtual reality method [9]. In addition, 65% of the participating 40 subjects stated a preference for having their shoulder ROMs taken with the VR method [9].

Strengths and Limitations

A strength of this study is that all four investigators are students in the Doctor of Physical Therapy Program at American International College and have had courses that teach goniometric measuring. Prior to the start of the study, all four raters underwent additional training specific to measuring cervical ROM by an independent clinician and faculty. This training provided a common reference source for goniometric measures, ensure measurement accuracy and language continuity, provided opportunity to limit test-retest errors and ensured consistent anatomical landmarks for goniometric measures. Another strength of this study is that the procedures were standardized to establish the same methods for each participant. A script was created and read by the investigators prior to securing the patients to the chair and the start of the measurement process.

Some limitations of this study include scheduling, utilization of eyewear, goniometer blinding as well as validation. Though the participants were secured to the chair using a gait belt, the placement of the belt may not have been high enough with respect to the thoracic spine to prevent compensatory movements. However, the study conditions may vary from real world application of virtual reality. The investigators stopped the subject and restarted the motion if compensation was visually identified. This could have influenced cervical ranges in the data collection particularly when goniometers used in the study were blinded to the tester, which may have served as a potential limiting factor, as the tester was unable to determine whether the starting position was at zero. Some of the participants preferred to place the goggles over their glasses while some had to remove their glasses all together to be able to wear the goggles. This

may have influenced the results of some if participants' vision was in any way compromised, however, this was not reported.

Conclusion

This study demonstrated that the virtual reality method using the Oculus Rift and XR Health clinical program is a reliable tool comparable to goniometric methods in assessing active cervical ranges of motions. In establishing the reliability of the combined Oculus and XR Health program tools, it provides the confidence to begin further clinical research and explore various treatment interventions/reassessments of patients going forward. The results also suggest a need to develop two strategic directions for patient engagement in the rehabilitation field. The first is to further investigate the virtual reality applications in clinical situations for validity in results. The second is to apply virtual reality in actual patient engagement and treatment interventions in the clinical setting. This study looked at the reliability of using virtual reality as an assessment tool compared with the standard clinical use of the goniometer. Understanding the validity relative to clinical cervical limitation would help in expanding need for these types of applications for remote treatment and telehealth efforts. Lastly, the inclusion of technologies, such as the use of virtual reality for assessment and therapeutic interventions, should be an integral component within physical and occupational therapy program curricula to responsibly prepare future physical and occupational therapy professionals.

References

1. Norkin C, White J. Measurement of Joint Motion: A Guide to Goniometry. Philadelphia, Pa: FA Davis Co. 2017.
2. Bahat HS, Sprecher E, Sela I, et al. Neck motion kinematics: an inter-tester reliability study using an interactive neck VR assessment in asymptomatic individuals. Eur Spine J. 2016; 25: 2139-2148.
3. Whitcroft K, Massouh L, Amirfeyz R, et al. Comparison of Methods of measuring Active Cervical Range of Motion. SPINE. 2010; 35: E976-980.
4. Gajdosik RL, Bohannon RW. Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. Phys Ther. 1987; 67: 1867-1872.
5. Farooq MN, Mohseni Bandpei MA, Ali M, et al. Reliability of the universal goniometer for assessing active cervical range of motion in asymptomatic healthy persons. Pak J Med Sci. 2016; 32: 457-461.
6. Sarig-Bahat H, Weiss PL, Laufer Y. Cervical Motion Assessment Using Virtual Reality. SPINE. 2009; 34: 1018-1024.
7. Mei H, Sheng L. Applying Situated Learning in a Virtual Reality System to Enhance Learning Motivation. IJIET. 2011; 1: 298-302.
8. Sahin NT, Keshav NU, Salisbury JP, Vahabzadeh A. Safety and Lack of Negative Effects of Wearable Augmented-Reality Social Communication Aid for Children and Adults with Autism. J Clin Med. 2018; 7: 188.
9. Carley P, Burkhart K, Sheridan C. Virtual Reality *vs.* Goniometry: Intraclass Correlation to Determine Inter-Rater Reliability for Measuring Shoulder Rand of Motion. J Allied Health. Summer. 2021; 50: 161-165.