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Original Research

Validation of an Infrared Camera System with a Joint Analysis Software as a Real Time Strength Training and Evaluation Tool

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ABSTRACT

OBJECTIVES Athletic performance and injury prevention are important for athletes and coaches. Different types of movement analyses have been created to aid in injury prevention and performance. The reliability of the Microsoft Kinect™ for movement analysis has not been widely tested. If reliable and accurate it could decrease the cost and time necessary for movement analysis. The purpose of this study was to determine if the Microsoft Kinect™ is an accurate measure of knee displacement during the parallel squat when compared to the Dartfish Team Pro Software 6.0.

METHODS Twenty nine healthy recreational athletes participated in the study and used the Dartfish Team Pro Software 6.0 to validate the Microsoft Kinect™ as a tool to measure knee displacement. Subjects performed a parallel squat with a 2.1m long dowel rod. This exercise was used to compare value between systems. The intraclass correlation coefficient and paired-samples t-test were used to compare Dartfish Team Pro Software 6.0 and Microsoft Kinect™. Intrarater reliability of each system was also assessed.

RESULTS There were 29 participants in the study. The interclass correlation coefficient for Dartfish Team Pro Software 6.0 and Microsoft Kinect™ showed that the Microsoft Kinect™ had a high-reliability ICC = 0.96. Intrarater reliability for Kinect™ and Dartfish were .98 and .99, respectively. The mean difference between systems for measured knee displacement was 1.06 cm. The mean for the Microsoft Kinect™ was 49.11 ± 1.9 and 50.16 ± 96 for the Dartfish ($p > 0.05$).

CONCLUSIONS The Microsoft Kinect™ is reliable against the Dartfish Team Pro Software 6.0 as a tool to measure knee displacement using the parallel squat. It appears for healthy young adults, the Microsoft Kinect™ is reliable for movement analysis.

Introduction

Anterior cruciate ligament (ACL) injuries from athletics are extremely common and costly. For example, annually more than 250,000 ACL injuries are estimated in the United States [1-3]. The total medical expenses, including ACL reconstruction and rehabilitation, are approximately $17,000 per injury. As a nation, over two billion dollars per year are spent on ACL injury rehabilitation [4,5].

Cost and incidence are not the only concerns for ACL injury and reconstruction. More than 30% of these individuals had moderate to severe disability in walking alone, 44% had moderate to severe disability during activities of daily living, and 75% could not return to their sport at the same level of

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performance as before the injury [6].

Furthermore, proper strengthening the muscles of lower extremities is required for ACL injury prevention because more than 70% of ACL injuries are occurred as non-contact injury during sudden deceleration prior to a landing or change of direction. For the reason, a back squat may serve as a training tool for injury prevention, as well as a tool for screening athletes for potential risk prior to participation in the activity [7]. The back squat can be used to assess neuromuscular control, strength, stability, and mobility throughout the body's joint segments or kinetic chain. However, neuromuscular strength and mobility problems are exposed through visible errors in technique. These errors consist of excessive trunk flexion, the knee moving into valgus, ankle pronation and the heel rising off the ground [7,8]. Furthermore, improvements in movement analysis software may have made it possible to combine tests assessing proper technique, quality of movement, and joint measurements. Thus, lack of neuromuscular control and poor biomechanics are risk factors for ACL injury that can be identified through movement analysis [9].

Therefore, the purpose of this study was to determine if the Microsoft Kinect™ accurately quantifies knee displacement during the back squat compared to the Dartfish analysis system. The Microsoft Kinect™ software has already demonstrated its ability to validly record anatomical landmarks in the form of postural control [10]. When correlated with 3D, 2D motion analysis has proved to be valid [11]. We hypothesized that when using intraclass correlation coefficients, we could demonstrate that knee displacement could be measured using the Microsoft Kinect™. Therefore, it is of importance and logic to use a 2D motion analysis, the Dartfish analysis system, to validate the Microsoft Kinect™ as a tool to evaluate hip, knee, and ankle displacement during the back squat exercise.

Methods

Subject

Twenty nine healthy recreational athletes (mean ± SD, male: n=14; age = 23.0 ±2.6 yr; height = 181.4 ± 6.4 cm; mass = 84.4 ± 10.6 kg, female: n=15; age = 24.0 ±3.9 yr; height = 169.3 ± 9.7 cm; mass = 69.1 ± 11.7 kg) who had current intramural competitive experience in volleyball, basketball, and/or soccer volunteered to participate in this study. The university's institutional review board approved (15-X-287) all forms and research protocols. A health history questionnaire was completed to ensure subjects were ready for physical activity. Any answers on questionnaire indicating they would be at physical risk during a bodyweight back squat excluded them from the study. Participants ranged between 18 - 29.9 kg/m^2 on the body mass index (BMI) scale. Any subject with a BMI ≥ 30 kg/m^2 were excluded from the study.

Instruments

The Dartfish™ Team Pro Software 6.0 (Dartfish USA Inc.; Alpharetta, Georgia, USA.) and Microsoft® Kinect™ for Windows® Software Development Kit (SDK) for tools of movement analysis. A JVC digital video camcorder (JVC, GZ-MG-27U, Long Beach, CA, USA) recorded the footage for Dartfish™ analysis. A 7 ft long one-half inch thick dowel rod was used for the representation of the barbell during the back squat movement. Black spandex clothing was worn during movement and/or tight fitting apparel. Silver colored circular reflective markers were placed on the patella.

Protocol

A video camcorder was placed directly in front of the subject in line with the patella above the ground, and 3m in front of the subject. Microsoft Kinect™ was placed at the same distance and just above the camera for the trials. Prior to data collection, a 38.1mm reflective marker was attached to each center of participants' patellar. A dowel rod was used to simulate a barbell and was placed on the upper trapezius muscles while in the shoulder width squat stance. This is appropriate back squat according to the NSCA essentials of strength and conditioning [12]. Researchers helped to center the simulated barbell on the upper back. Subjects picked up dowel rod placed it on their back and while in frame began the squat movement on researchers command. During the downward movement phase, subjects kept elbows tucked and the chest up and out. While maintaining the same torso position the subject would continue to flex at knees and hips. The proper squat depth was the point in which a subject's thighs became

Table 1. Mean ± SD and p value for Dartfish™ Team Pro Software 6.0 and Microsoft Kinect™

	Condition		
Dependent variable	Dartfish	Kinect	p value
Knee displacement	49.11 ± 1.96	50.39 ± 0.99	0.49

Table 2. Intraclass Correlation for Measures of Knee Displacement Using Dartfish™ Team Pro Software 6.0 and Microsoft Kinect™

	Kinect vs. Dartfish
	$ICC_{1,k}$ (95%CI)
Knee Displacement	0.96 (0.92-0.98)

Note. $ICC_{1,k}$: Type 1,k intraclass correlation coefficient CI: 95% confidence interval Upper 95% reported in brackets.

Table 3. Test-Retest Reliability for Measures of Knee Displacement Using Dartfish™ Team Pro Software 6.0 vs. Kinect™

	Kinect	Dartfish
	$ICC_{1,k}$ (95%CI)	$ICC_{1,k}$ (95%CI)
Knee Displacement	0.98 (0.96-0.98)	0.99 (0.99-1.0)

Note. $ICC_{1,k}$: Type 1,k intraclass correlation coefficient CI: 95% confidence interval Upper 95% reported in brackets.

parallel with the floor. In the up phase, the subject stood up by extending the hips and knees simultaneously while maintaining a flat back until in an erect position. Subjects were instructed to squat with their feet flat and not translate their weight to their toes during the squat movement. The participant was instructed on how to perform the squat technique, practice trials were performed until the subject felt comfortable with the movement. The subject performed five recorded trials.

Statistical Analysis

Intraclass Correlation Coefficient ($ICC_{1,k}$) was used as measures to determine the agreement and the strength of the relation for the knee displacement from the two different biomechanical data analysis systems: Dartfish™ and Kinect™. Also, the intrarater reliability was used to compare results of each Dartfish™ and Kinect™ with $ICC_{1,k}$. Finally, a paired t-test was performed to compare the means across the 5 trials between the Dartfish™ and Kinect™ and significance was set at $p < 0.05$ (SPSS v.22, IBM, Inc., Chicago, IL, USA).

Results

For the value of the Microsoft Kinect™, compared to the Dartfish™, no significant difference between the mean values for knee displacement obtained ($t(29) = -1.618$, $p > 0.05$; Table 1). We also found a strong linear relationship between the analysis tools for knee displacement during the back squat as $ICC_{1,k} = 0.96$ (Table 2). Furthermore, Dartfish™ and Kinect™ showed a high degree of reliability (Table 3) for the knee displacement corresponding to the back squats ($ICC_{1,k} = 0.98$ and 0.99, respectively).

Discussion

The aim of this study was to evaluate the ability of the Microsoft Kinect™ to obtain accurate measures of knee displacement during the back squat. Using the Dartfish™ software as the tool to measure reliability, we hypothesized that when using intraclass correlation coefficients, we could demonstrate that knee displacement could be measured using the Microsoft Kinect™.

We found that the Microsoft Kinect™ values for knee distance at the bottom of the parallel back squat correlated well with the values obtained by the Dartfish analysis. The intra-class correlation value was 0.96 for the two systems (Table 3). Comparison between the Dartfish and Kinect™ showed good evidence that the Microsoft Kinect™ is useful for movement analysis where immediate feedback is necessary. Another important finding was the Microsoft Kinect™ showed accuracy without the use of reflective markers, eliminating a timely step in a standard motion analysis.

The Dartfish™ Team Pro Software 6.0 that was used to compare Microsoft Kinect™ had accurate intrarater reliability, meaning during analysis of raw video footage where knee displacement was measured at the bottom of the squat the distances obtained by the researcher were consistent among trials. This also held true for the Kinect™ where the system could repeatedly obtain the same measure for knee displacement among individuals. These values are important to mention during a discussion of the reliability of Microsoft Kinect™ as a tool to measure knee displacement. Often, during training sessions in the weight room or on the playing field where the Kinect™ could be used to correct errors in technique, the activity will be repeated many times in practice.

The reliability of the Microsoft Kinect™ to detect knee displacement is conducive to the recent research involving the Microsoft Kinect™ software. Dolatabadi et al., found similar results for gait indicating the Kinect™ software has the ability to accurately measure these gait patterns. Our research showed an ICC of r = 0.96 which shows a higher correlation than the previous study (report their ICC here in parentheses). [13]. And statistically, greater than 0.75 for ICC is considered as an excellent correlation [14]. Other similar research using the second version of the Microsoft Kinect™ to identify joint center location showed a large range of accuracy when compared to a global coordinate system [15].

These researchers found that there was not much improvement from the first version of the Microsoft Kinect™. Xu and McGorry [15] stated that previous research demonstrates good measurement agreement regardless of the version of Kinect™ for body segments lengths, joint angle and, more importantly, the displacement of certain joints while testing specific body postures. The claims of these researchers support our findings where the agreement of the joint displacements from the two different software was highly correlated. These findings may elude to the fact that the specificity of the software used is important. For example, in our study, we used the back squat to determine knee displacement. During this specific activity, the measures for each participant in the study were highly repeatable, with a difference between measures ranging from 0.03 to 11.63 cm. These general tasks may be well suited for using the Microsoft Kinect™ for motion analysis. However, large, complex movements where many joints and rotational movements are involved may not be accurately analyzed by the current version of the Microsoft Kinect™.

The Kinect™ is limited by its inability to detect 3D joint motions. When the knee joint rotates in the frame, it becomes difficult to track. As of now, the movements are limited to the frontal plane with Kinect™ being aligned on the sagittal axis. There are many athletic events that the Kinect™ would be useful for analyzing. Dynamic movements, other than the back squat, include the vertical jump, which is a common measure of power, the 40 yard dash, which measures speed and acceleration, and the drop landing, where errors in muscle activation and biomechanics of lower extremities are often exposed. The Kinect™ would be useful in practice for basketball players and volleyball players where knee displacement often results in injury during the drop landing. A limitation of the study is that all subject were normal weight individuals (BMI: 18 - 29.9 kg/m^2). Overweight individuals may be difficult to obtain accurate measures on tracking makers or infrared image from Kinect™.

Conclusions

The purpose of the present study was to examine the capacity of the Microsoft Kinect™ as a reliable tool to measure knee displacement in healthy weight populations. For small, single-plane specific movements, the Microsoft Kinect™ obtains valid, reliable measures of knee displacement compared to using Dartfish™ Team Pro Software. The Microsoft Kinect™ is a low-cost, quick way to find knee displacement without the use of reflective markers. Future research in the Kinect™ software are needed to further validate this method for analyzing multi plane, quick movements.

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Conflicts of Interest

The authors declare no conflict of interest.

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