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Reliability and Validity of Angular Joint Velocity Using Peak Motus 2000 Motion Analysis and Kin-Com Isokinetic Dynamometer

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RELIABILITY AND VALIDITY OF ANGULAR JOINT VELOCITY USING

PEAK MOTUS 2000 MOTION ANALYSIS®

AND THE

KIN-COM ISOKINETIC DYNAMOMETER®

by

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This Independent Study, submitted by Mark Wagner in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title	Reliability and Validity of Angular Joint Velocity using Peak Motus 2000 Motion Analysis® and Kin-Com Isokinetic Dynamometer®
Department	Physical Therapy
Degree	Master of Physical Therapy

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Signature Mark Wagner

Date 12-5-00

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ABSTRACT

Background and Purpose: Use of motion analysis systems for the study of human motion in research settings and clinical settings is becoming more prevalent. In a traditional sense, motion analysis systems are used for gait analysis; most recently, they are being utilized to analyze spinal motion, foot motion, and components of motion during sporting activities. Questions about the accuracy of computerized motion analysis systems and the precision and reliability of the digitizing process remains. The purpose of this study is to determine the validity of the Peak Motus 2000 motion analysis system in calculating dynamic velocities and range of motion. Methods: Six healthy subjects (three females and three males) had reflective markers placed on the right ankle joint. Video cameras filmed the subject's ankle movements while on the Kin-Com Isokinetic Dynamometer. The subjects were taken through five repetitions each of the following passive speeds: 60, 150, and 240 degrees/second. The Kin-Com Isokinetic Dynamometer was then utilized in a passive mode without subjects by placing reflective markers on the lever arm. The Peak Motus 2000 motion analysis computer software program was used from recorded video motion with a subject attached to the apparatus to determine angular joint velocity. Statistical analysis was completed comparing data sets. Results: In summary, the compiled standard deviation values from lowest to highest are Kin-Com, Peak Performance lever arm and Peak Performance skin marker measurement. This indicates that subject motion analyzed by skin marker angular velocity measurements had a greater variability and therefore a higher chance of being inaccurate. It was found that the Peak Performance had a trend towards overestimating set angular velocities, which became larger as the speed was increased. Conclusion: This study found that at 60 degrees/second there was no significant difference in reported angular velocity between the Kin-Com and the Peak Performance and a significant difference in reported angular velocity at 150 and 240 degrees/second. It also showed that the Peak Performance tended to be more accurate at lower speeds and decreased in accuracy as the speeds increased. The Peak Performance system generally overestimated the angular velocity at each speed.

CHAPTER I

INTRODUCTION

Use of motion analysis systems for the study of human motion in research settings and clinical settings are becoming more prevalent. In a traditional sense, motion analysis systems are used for gait analysis; most recently, they are being utilized to analyze spinal motion, foot motion, and components of motion during sporting activities. Motion analysis systems offer investigators a method of analyzing and quantifying sophisticated parameters of movement such as range of motion and velocity. This expands the investigator's power of observation and judgment.

Definitions

For the purpose of this study, the following terms are defined.

Digitize: The process of grabbing NTSC video and transferring it, via the frame grabber, onto the Peak Motus 2000 computer system for analysis and display.[1]

Velocity: time rate of linear motion in a given direction: a vector quantity equal to speed in a particular direction and relative to a stated frame of reference.

Isokinetic Dynamometer: a hydraulically driven, microcomputer-controlled device designed to control the velocity of limb movement while measuring torque and work during eccentric and concentric isokinetic loading.[2]

Motion Analysis: a biomechanical collection and analysis of two-dimensional and three-dimensional data via computer.[3]

Problem Statement

Questions about the accuracy of computerized motion analysis systems and the precision and reliability of the digitizing process remains. Inaccurate diagnosis of segmental velocities during gait analysis while using motion analysis may lead to an improper intervention. The establishment of the reliability and validity of measurements obtained with these systems is critical, given the importance of clinical based decisions upon the obtained data. Measurements taken with various motion analysis systems support it's precision when the subject is not in motion (static). Since no motion is occurring during static testing, the precision and accuracy of motion analysis systems are overestimated. It has been found that in determining velocity in degrees/second during motion (dynamic) the accuracy of the Peak 5 Motion Analysis System is best when filming motion at speeds less than 150°/second. The accuracy of the system declines as dynamic motion increases in speed.[4,5,6]

Dynamic range of motion and velocity measurements may be more indicative of impairment than static measurements, as static measurements do not accurately represent human motion. Considering that human motion occurs at speeds far greater than 150°/second, it is critical to determine the accuracy of angular joint velocities with the use of motion analysis systems at faster speeds.

Purpose of Study

The purpose of this study is to determine the validity of the Peak Motus 2000 motion analysis system® in calculating dynamic angular velocities and range of motion. The Kin-Con isokinetic dynamometer's® relationship between actual velocity and the investigators set velocity has been proven to have a nearly perfect linear relationship.[7]

Therefore, this study will compare the measurements of varying velocities recorded by the Peak Motus 2000 motion analysis system® to the investigator's set velocities on a Kin-Com isokinetic dynamometer®. The Kin-Com will be used in a continuous passive mode throughout the study. Data will be compiled between the two machines with and without subjects and at varying velocities to determine if there is statistical variance. Sagittal plane motion of ankle plantar flexion and dorsiflexion will be used in this study as a general representation of human motion.

Significance of Study

This study will compare angular velocity and range of motion data gathered from the Peak 2000 motion analysis system and the Kin-Com dynamometer. An attempt to determine the Peak Motus 2000 reliability and validity in calculating angular velocity in a simulated clinical setting. This information may be beneficial to physical therapists that use the Peak Motus 2000 systems for evaluation of patient motion. The increased popularity of motion analysis for evaluation of dynamic motion, suggests a real need for this study.

Research Questions

1. What is the angular velocity accuracy of the Peak Motus 2000 compared to the Kin Com at 60, 150, and 240 degrees per second?
2. How does use of a subject affect angular velocity of the Kin-Com and/or the Peak Motus 2000 system?
3. How may skin marker placement effect velocity measurements?

Hypothesis

Null hypothesis: There is no significant difference in reported angular velocity between the Kin-Com and Peak Motus 2000 at 60, 150, and 240°/second.

Alternate hypothesis: There is a significant difference in reported angular velocity between the Kin-Com and Peak Motus 2000 at 60, 150, and 240°/second.

CHAPTER II

LITERATURE REVIEW

The present study will attempt to determine the accuracy of velocity measurements of the Peak Motus 2000. This study will be comparing the velocity measurements made by the Peak Motus 2000 to the velocity measurements taken by a Kin-Com dynamometer.

Motion Analysis

Motion measurement is a term used in biomechanics to describe the collection and analysis of two-dimensional and three-dimensional data. The data can be processed to analyze the various movements of an object, performing such calculations as displacements, velocities, acceleration, and angles.[3] This data is collected from video cameras, videotape, and a variety of analog devices. Many motion analysis systems have been developed over the past 15 years, as the popularity of its use has expanded.

Motion analysis systems are used in various fields such as research, sports science, industry, and health care. Research applications include: locomotion, flight mechanics, feeding mechanisms, and cell motility. Sports science applications include: determining range of motion for any joint to optimize performance and prevent injury, analysis of an athletes technique, enhancement of athletic performance and skills using quantitative data, testing of sporting equipment, synchronization of movement data with analog data from EMG, and calculation of precise kinematic measurements. Industry applications include: quantifying repetitive motions that cause cumulative trauma disorders (i.e. carpal tunnel syndrome), determining job task or product use range of motion, assessment of human/device interaction, and designing ergonomically sound devices and workstations. Health care applications include: quantification and qualification of prosthetic devices before and after fitting patients, calculation of precise kinetic parameters for pathological gait evaluation, and assessment of range of motion before and after rehabilitation.[3]

Three-dimensional and two-dimensional kinematic measurements can be obtained with a variety of commercially available motion analysis systems, including the Ariel Performance Analysis System™, the Peak Performance Analysis System™, The Expert Vision Motion Analysis System™, and the WATSMART optical tracking system™. Although the capabilities of these systems vary, each system uses a mathematical method to generate 3-D or 2-D coordinates from planar views. Motion analysis systems have been simplified with the creation of features such as on-line digitization and frame grabbing boards used to convert video analog images into digital images. Although the process of motion analysis has become much easier over the years, questions remain about the accuracy and reliability of resulting measurements. Each systems accuracy cannot be directly compared to others because each system gathers data using different technology, including marker systems and methods of camera synchronization, and this data may not be similar to the data obtained with another system.[8]

The Peak Performance motion analysis system with the software version Peak Motus 2000 is used in this study. The Peak motion analysis system uses a series of passive reflective markers that are placed on a subject, and these are then filmed using a video camera with Super VHS videotapes. The Peak system is available as a two-dimensional (2D) system that uses just one camera or a three-dimensional (3D) system that uses a number of synchronized cameras. The videotapes are digitized on a personal computer to produce data on linear changes in acceleration and velocity and angular changes in acceleration and velocity.[4] Peak Performance was founded in 1984 with the goal of producing a computer and video based biomechanical analysis tool in preparation for the Los Angeles Olympic games to help athletes improve performance. Since that time, Peak has expanded the use of its products to a wide variety of applications that include commercial, industrial, medical, and biological. Continuous improvements have been made over the years by using customers as active participants in designing systems to accomplish their goals. This has led to the recent release of Peak Motus 2000.[3] To our knowledge, no studies outside of Peak Performance Technologies, Inc. have been conducted verifying the accuracy of velocity measurements of the Peak Motus 2000 software.

Isokinetic Dynamometer

An isokinetic dynamometer is a device that provides a mechanical means of maintaining a constant rate of limb movement regardless of the magnitude of forces generated by the muscles.[9] Various isokinetic dynamometers include the Biodex B-2000 (Biodex Corporation, Shirley, NY), Cybex II (Cybex, Division of Lumex, Inc., Ronkonkoma, NY, 11779), Kinetic Communicator (Kin-Com, Chattecx Corp., Chattanooga, TN), and the Lido 2.0 (Davis, CA). Data from these different dynamometers may not be comparable.[10] Therefore, values recorded from one dynamometer should not be compared to those obtained from other dynamometers. If data is compared, caution should be used.[11]

Isokinetic dynamometers are hydraulically driven, microcomputer-controlled devices designed to control the velocity of limb movement while measuring torque and work during eccentric and concentric isokinetic loading.[2] Isokinetic motion is constant velocity movement. The Kin-Com monitors the force, angle, and velocity signals through feedback loops, which monitor the signal transducers.

Mayhew et al.[7] has shown that the velocity measurements on the Kin-Com have a nearly perfect linear relationship at all speeds when compared to an external recording system. Farrell and Richards[12] found lever arm speed to be within 1.5% of the target speed, which is a valid and reliable measurement. They concluded that use of the Kin-Com is acceptable for most clinical and research applications.

The Kin-Com has features that make it an easy, adaptable apparatus to utilize in the clinic. Subjects can be placed in a variety of positions for testing and exercise. Subject testing and exercise are controlled by the investigator using a personal computer and a software program supplied with the device. The Kin-Com software allows the investigator to control the velocity and range of motion at which the lever arm will move.

The limb to be tested is attached to the dynamometer via a padded cuff, which is attached to a housing containing strain gauges. The housing can be moved by the operator along a metal lever arm to accommodate different limb lengths. The distance from the pad to the axis of rotation is entered into the computer for each individual subject before the testing begins. It is important for the axis of rotation of a body segment and the axis of the dynamometer to be properly aligned in order to reduce errors in the computer calculations.[13]

The Kin-Com lever arm is moved by a hydraulic motor that is controlled by the computer. The user is allowed to regulate the acceleration of the lever arm at the beginning of the motion and deceleration of the lever arm at the end of the motion by setting what the Kin-Com manual refers to as turn points. Turn points can be set at high, medium, or low settings.[7] The high setting on the Kin-Com maximizes the amount of time the subject's limb is moved at a constant velocity as set by the investigators, where as a low setting produces a gradual acceleration or deceleration towards a constant velocity. The Kin-Com provides multiple exercising strategies to choose from including: isokinetic, isometric, protocol, passive, isotonic, and sequential. The Kin-Com can be set at velocities between 30 to 250 degrees per second.

In the present study, the data being collected from the Kin-Com will be angular velocity measurements, which are obtained by the machines tachometer. Velocity is a vector quantity with both magnitude (speed) and direction. Therefore, constant velocity implies both constant speed and direction of a moving object.[14] The passive motion setting will be used, which will move the lever arm without the necessity of an external force. Some researchers have recommended calibration of the isokinetic unit every two weeks.[15] According to the Kin-Com manual, this machine has a self-calibrating system. If the machine is not properly calibrated, there will be an error message on the screen.[16] The University of North Dakota Physical Therapy Department's Kin-Com was calibrated in July of 2000 (1.5 months prior to the study). Signals from the force, angle, and velocity transducers of the Kin-Com are processed at 100 Hz by the systems' analogued digital board and then displayed on the computer monitor.

Validity

Mayhew et.al[7], assessed the relationship between the actual velocity that the lever arm moved and the user-set velocity (velocity set by the investigator using the Kin-Com software). The actual velocity of the lever arm was determined from the angular displacement signal using the data analysis software (Dadisp Worksheet) with a sampling frequency of 500 Hz. The velocity of the Kin-Com lever arm was then tested without any externally applied force in a passive mode, no human subject was used. Velocities were tested in 30 degrees/second increments through a range of 30 to 210 degrees/second. Measurements were conducted on two separate days in order to assess the agreement of measurements. The coefficient of determination for the velocity measurements was above .99 for all conditions (Table 1). This study demonstrates that constant-velocity measurements obtained with an external recording system has a nearly perfect linear relationship with the user-set velocities on the Kin-Com isokinetic dynamometer with high acceleration and deceleration settings. This study provides evidence that passive Kin-Com constant-velocity measurements are valid and reliable. Schrag and Rodgers[17] conducted an experiment to test the validity of angular measurements made by the Peak 5 system. A universal goniometer, with one-degree increments, was video taped. A reflective marker was placed at the end of each arm of the goniometer to represent the hip and the ankle. A third reflective marker was placed over the axis of the goniometer to represent the knee. The goniometer was moved by 15 degree increments into eleven different positions starting at 180 degrees, equivalent to

Table 1. Relationship of velocity measurements between the Kin-Com isokinetic dynamometer and an angular displacement signal using the data analysis software (Dadisp Worksheet) with a sampling frequency of 500 Hz (adapted from Mayhew et.al.[7])

Condition	r^2(coefficient of determination)	Slope	Intercept
User-set versus actual[a]			
Day 1	.99	1.01	-1.43
Day2	.99	1.01	-1.49
Day 1 (up)[b]	.99	1.01	-1.23
Day 2 (up)[b]	.99	1.01	-1.29
Day 1 (down)[c]	.99	1.01	-1.64
Day 2 (down)[c]	.99	1.01	-1.61
Actual Velocity[d]			
Day 1 versus Day 2	.99	1.00	-0.01
Day 1 versus Day 2 (up)	.99	1.00	-0.06
Day 1 versus Day 2 (down)	.99	0.99	0.03

[a]Velocity selected by investigator using Kin-Com software compared with actual velocity
of lever arm calculated from rate of displacement of lever arm.
[b]Upward movement of lever arm only.
[c]Downward movement of lever arm only.
[d]Actual constant velocity of lever arm calculated from rate of displacement.

full knee extension and finishing at 30 degrees, equivalent to full knee flexion. Each position was filmed and analyzed. Results show a very high level of agreement, with a mean percentage of difference of 0.27 degrees and a SD 0.24 degrees (Table 2).[17] A study by Bratton and Ross[18] demonstrates the validity of static joint angle measurements with the Peak 5 motion analysis software when compared with goniometric measures. A (r= 0.992) was found between the two devices. Other studies with motion analysis systems other than the Peak system have shown similar results with static measurements.[8,19] However, it is important to remember that static evaluations do not accurately represent the clinical environment and the accuracy of motion analysis systems used during dynamic motion. As no movement occurs, a static test of precision and accuracy may overestimate the capabilities of motion analysis systems.[4]

In a study that is the most closely related to the present study, Selfe[4] tested the validity of the velocity measurements made by the Peak 5, in which, an isokinetic dynamometer (Biodex) was video taped. A reflective marker was placed at the end of each arm of the Biodex to represent the hip and the ankle; the third reflective marker was placed over the axis of the Biodex to represent the knee. Passive mode, using a hard end stop was selected as the most appropriate setting to videotape. The Biodex hard end stop is comparable to the Kin-Com high acceleration/deceleration setting. The Biodex was set to move at 5 different speeds, 30, 60, 90, 120, and 150 degrees/second. Six repetitions at each speed were videotaped, and one repetition representing each of the speeds was later analyzed. The results of this study demonstrated a high level of agreement. However, the Peak 5 showed a trend towards overestimating the velocity. The largest difference in readings between the two machines was 2.3 degrees/second, which occurred

Table 2. Comparison of angular measurements of the goniometer to the Peak 5, recorded in degrees (adapted from Schrag and Rodgers[17])

Goniometer	180	165	150	135	120	105	90	75	60	45	30
Peak 5	180.3	165.26	149.8	135.2	119.9	104.5	90	74.3	59.5	45.1	29.8
Mean	180.15	165.15	149.9	135.1	119.95	104.75	90	74.65	59.95	45.05	29.9
Standard deviation	0.21	0.21	0.14	0.14	0.07	0.35	0	0.49	0.07	0.07	0.14

when the speed of the Biodex was at 150 degrees/second. The mean difference between the measurements obtained by the two pieces of equipment was 0.96 degrees/second (Table 3). Schrag and Rodgers[17] performed a similar study in which a Cybex isokinetic dynamometer was filmed at six different velocities. Accuracy ranged from 0.08 to 4.9 degrees/second, the authors noted that the accuracy was best at speeds of less than 150 degrees/second. The authors concluded that the Peak 5 could provide measurements that were accurate and reliable for most clinical applications. Experiments from Selfe[4] and Schrag and Rodgers[17] confirm the Peak 5 is most accurate when filming movement at slower speeds.

Table 3. Comparison of velocity measurements, in degrees per second, recorded by the Biodex and the Peak 5 (Adapted from Selfe[4]).

Set speed	30	60	90	120	150
Biodex	29.1	58.4	87.5	117	146.6
Peak 5	29.1	58.6	88	118.8	148.9
Mean	29.1	58.5	87.75	117.9	147.75
Standard deviation	0	0.14	0.35	1.27	1.62

There are many potential sources of error when motion analysis systems are used. These errors include application of markers by several investigators, removal and reapplication of markers and skin movement over bony landmarks. If these sources of error are not controlled or minimized, the reliability of clinical kinematic measures may be jeopardized.[5,19]

Skin movement artifact is a hard problem to solve due to the fact that during dynamic motion the parts of the skeleton move under the overlying skin. One way to reduce skin movement error is to use sites on each segment where the skin movement is small enough to be neglected. Schamhardt et. al.[20] states that correction for skin movement will hardly be necessary in most locomotion studies. Only when accurate data is required on the length and length changes of muscles and tendons will correction may be inevitable.

On the contrary, Lafortune et al.[21] measured skin marker displacements using the Peak 5 Motion Analysis system and videofluoroscopy during loaded and unloaded cycles of knee flexion and extension. The position of the reflective markers were on the greater trochanter, lateral condyle of the knee, and the lateral malleolus. The results indicated that movement of the markers relative to the underlying bones occurred, ranging from 0.9cm to 7cm. Twenty-five of the forty measurements showed a movement of less than 2.5 cm. When comparing loaded to unloaded conditions, less marker movement was evident during the loaded activity. This is an important consideration, as most functional movements of the lower limb occur during weight bearing activities.[4]

CHAPTER III

METHODS

Subjects

Six healthy subjects (three females and three males) gave their informed written consent to serve as subjects in this study. Individuals with prior ankle injuries were excluded from this study. The age of subjects ranged from 22-25 years (X=23.2). The height of subjects ranged from 64-72 inches (X=68.8). The weight of the subjects ranged from 126-204 pounds (X=151.5) (See Table 4).The study was conducted at the University of North Dakota Physical Therapy Department. The Institutional Review Board at the University of North Dakota approved the study.

Table 4. Descriptive Statistics of Subjects

Subject	Height (in.)	Weight (lbs.)	Gender	Age (years)	Ankle Plantarflexion (degrees)	Ankle Dorsiflexion (degrees)
One	64	131	M	25	57	21
Two	68	138	F	22	61	9
Three	72	204	M	24	69	12
Four	72	166	M	23	63	4
Five	68	126	F	23	68	8
Six	69	144	F	22	68	8

Instrumentation

Video

Three reflective markers were placed on each subject to represent the ankle joint center in the sagittal plane. The exact placement is detailed in the protocol section below. A Pulnix 60/120 Hz camera designed for the Peak System (Peak Performance Technologies, Englewood, CO) was used to film ankle plantarflexion and dorsiflexion movements. Video data was collected at 60 Hz was utilized with a shutter speed of 1/250 of a second. The trials were video taped using a JVC model BR-S378U videocassette recorder (JVC of America, Elmood Park, MD) on SVHS videotape. The videotape was encoded with a SMPTE time code generator.

After recording all the trials, the subjects' movements were digitized using the Peak Motus 2000 Software package. The tapes were played back on a Sanyo Model GVR-S955 (Sanyo, Campton, CA) videocassette recorder for the purpose of digitization.

Isokinetic Dynamometer

The Kin-Com (model 125AP with software version 4.06, Chattecx Corp., Chattanooga, TN) isokinetic dynamometer was used to evaluate joint angular velocities in this study. Signals from the force, angle, and velocity transducers of the Kin-Com are processed at 100 Hz by the systems analogue digital board and displayed by the computer monitor. In this study right ankle plantar flexion and dorsiflexion were tested in the continuous passive motion mode. A comfortable amount of ankle dorsiflexion was determined by passively dorsiflexing while the subject was secured to the Kin Com device. This position was then set as the ending point for dorsiflexion. Plantarflexion motion was determined by moving the Kin Com lever arm 40° toward plantarflexion.

This allowed a consistent 40° of motion to be assessed with each subject in each trial of the study. At no point was the motion painful or restrictive to the subject. The acceleration and deceleration settings of the lever arm were set on a high speed, this allowed the subject's limb to obtain a constant velocity in the shortest possible time.

Skin Marker Placement

The skin over the right ankle was prepared by cleansing it with rubbing alcohol in order to maximize adherence of the three reflective markers. The axis of the ankle joint was defined by the placement of three passive reflective markers. The three markers defined two segments representative of the foot and leg of the subject. The leg segment was represented by one reflective marker placed over the center of the medial tibial condyle and another marker placed on the center of the tibial malleolus. The foot segment was represented by one reflective marker placed over the medial aspect of the first metatarsal head and the medial tibial malleolar marker (figure 1 and 2).

Procedure

Three examiners administered the testing, with at least two present at each session. One examiner was assigned to place the three reflective markers on each subject. The same examiner also recorded all height, weight, and ankle range of motion measurements. A different examiner administered all Kin-Com and motion analysis procedures. All research was supervised by one investigator to exclude any potential examiner-related variability.[22]

Data collection took place at the Physical Therapy Department at the University of North Dakota. Subjects were scheduled upon their availability on the day of data collection. Upon arrival, subjects were informed of the data collection procedure and

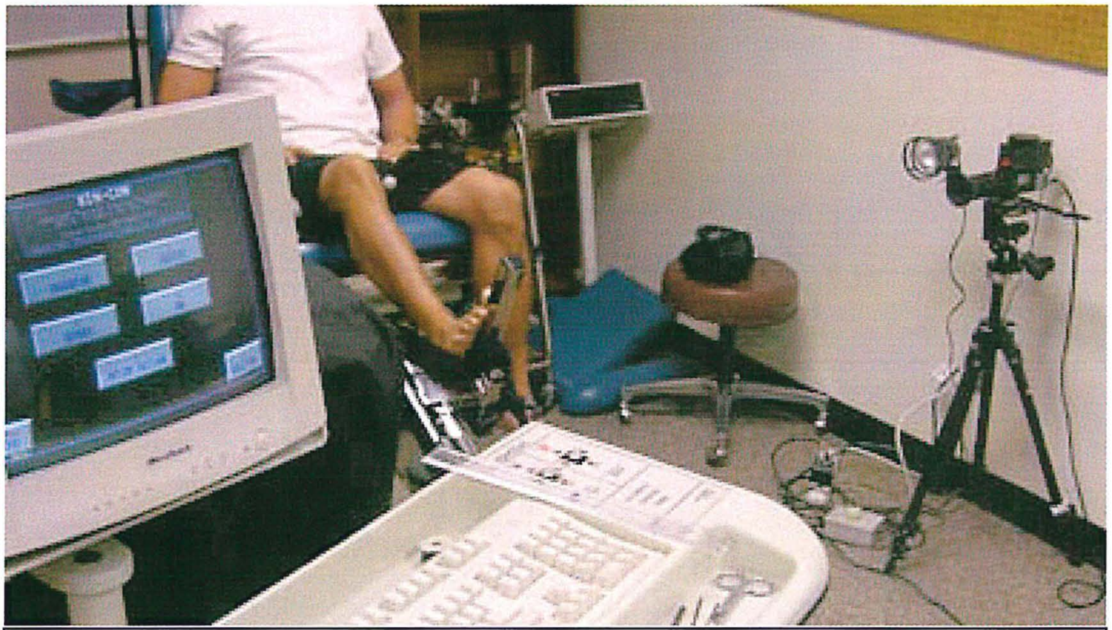

Figure 1. Equipment set-up.

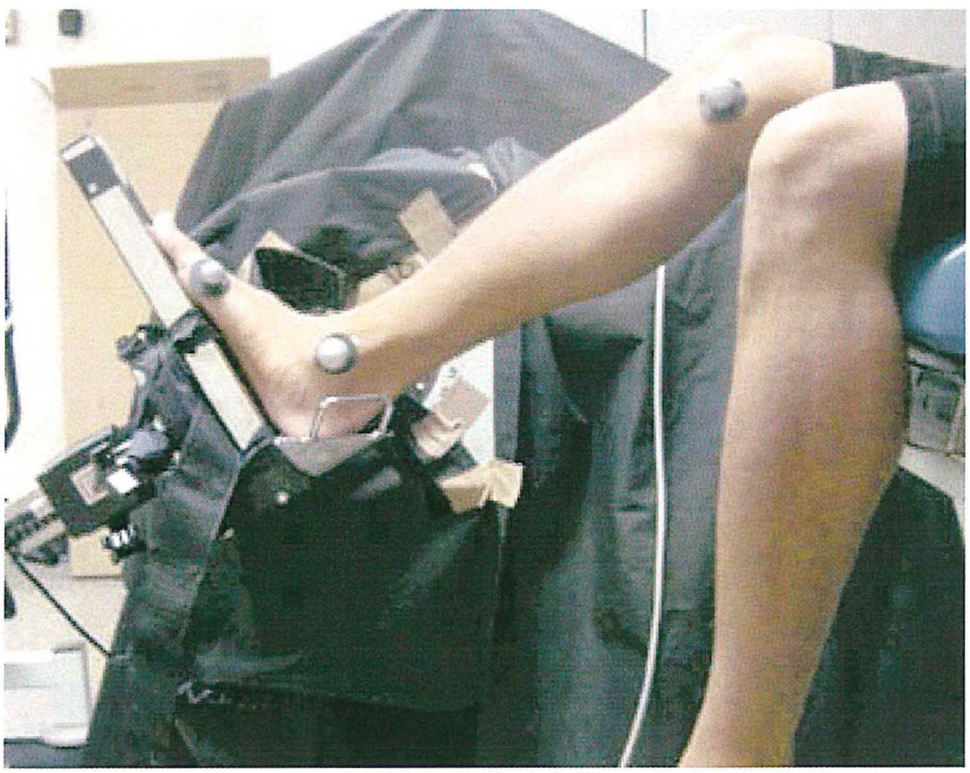

Figure 2. Reflective markers representing ankle joint center in the sagittal plane

asked to sign a consent form as explained previously. Subjects wore athletic shorts with no socks or shoes so the lower limb could be fully exposed during testing.

The subject's height, weight, age, gender, and ankle plantarflexion and dorsiflexion range of motion were recorded for future statistical analysis. Height, weight, and ankle plantarflexion and dorsiflexion range of motion were measured with standard devices. Passive reflective markers were attached to the right ankle joint, as described in the reflective marker section, using double-sided tape. The reflective markers were placed in identical landmarks for all subjects. Before testing, each subject was instructed to perform a warm-up of twenty repetitions of non-weight bearing ankle plantarflexion and dorsiflexion.

Each subject was orientated to the Kin-Com machine and the testing procedure was explained. The subjects were in a seated position on the Kin-Com and settings for each subject were established and recorded at that time, following the protocol for ankle plantarflexion and dorsiflexion.[15] The subjects were positioned on the Kin-Com with an arbitrary right knee flexion angle between 50 and 55 degrees of flexion to fit the subject's specific physical dimensions. The subject's left lower limb was positioned so that all reflective markers could be visualized. Subject positioning was standardized to create consistency and allow unrestricted range of motion.[23] Each subject's right ankle rotational axis was aligned with the dynamometer's axis of rotation, using the tibular and fibular malleoli as the center. It is important for the axis of rotation of a body segment and the axis of the dynamometer to be properly aligned in order to reduce errors in the computer calculations.[13] The right forefoot was secured to the dynamometer arm by a stabilization strap.

Each subject was allowed the use of a safety button as a precautionary measure. Upon pushing of the safety button, all dynamometer movement would cease. The video camera was placed to the left of the subject and filmed the subject's ankle movements while on the Kin-Com.

The test procedure consisted of one practice and one test session of six repetitions for each of the test speeds (60, 150, and 240 degrees/sec) in continuous passive mode. The right ankle range of motion for each trial and speed for all subjects was set at approximately 5 degrees of dorsiflexion and 35 degrees of plantarflexion, for a total 40 of degrees of motion. There was a one- minute interval between the sets to allow time to adjust the different speeds. The subjects were instructed to allow passive motion to occur while maintaining the positioning of their right lower limb according to protocol. To ensure no effort on the part of the subject, verbal reminders were given during both the practice and test sessions.

Before videotaping, the camera was calibrated by recording a known distance of 30 cm through the video collection system. This video footage was then transferred to the Peak Motus hardrive to represent the calibration frame. Each subsequent trial was calibrated to the known distance of 30 cm. Three cycles (one cycle is full plantarflexion—full dorsiflexion—full plantarflexion) at each speed of 60, 150 and 240 degrees/second were transferred to the Peak Motus system through the frame grabber board and cropped. The video files were then digitized and analyzed using the Peak Motus 2000 system.

Data Conditioning

The data was conditioned to analyze the middle fifty percent of each plantarflexion/dorsiflexion action (one cycle). The first and last quartiles were removed from each cycle to rid acceleration and deceleration velocity measurements so that the steady state values could be analyzed. The amount of frames removed was dependent upon the set angular velocity of the Kin-Com. Because the Kin-Com measures 100 frames per second, whereas the Peak Performance measures 60 frames per second more frames were removed from the Kin-Com data.

Angular velocity data was also changed to all positive values so it could be statistically analyzed.

Statistics

The Wilcoxin Signed Rank test, Matched-Subject design T-test, and Single Sample T-Test were used to analyze results obtained in this study. The significance level was set at $p \leq .05$.

CHAPTER IV

RESULTS

The data gathered failed to meet all of the assumptions for parametric analysis, so non-parametric tests (Wilcoxin) were run on all pair-wise comparisons. Several of the tests demonstrated significant differences. Paired T-Tests were also used and found identical results to the Wilcoxin tests relative to significance. As researchers, we have decided to report the results of the T-tests.

It is important to note that although specific speeds were set on the Kin-Com Isokinetic Dynamometer (60,150, 240 degrees/sec), averages of angular velocity were compiled from acceleration and deceleration measurements. The total data set for each speed and subject was conditioned by taking the middle fifty percent for each plantarflexion/dorsiflexion action (one cycle). The data from the first and last quartile was discarded to reduce variance between the two machines. Data was collected for all six subjects. However, marker movement outside of the camera view did occur with two subjects. Therefore, data from these trials was not analyzed.

Angular Velocities of PPSEG (Peak Performance lever arm measurements *with* Subjects) vs. KC (Kin-Com *with* subjects)-Matched Subject Design T-Test

There was a significant difference in angular velocity between the Peak Performance lever arm measurements with a subject and Kin-Com with a subject at 150 and 240 degrees/second. The Peak Performance lever arm measurements were higher at each speed (See Table 5). The devices demonstrated a significant negative correlation at 240 degrees/second.

Angular Velocities of PP (Peak Performance skin marker measurements *with* Subjects) vs. PPSEG (Peak Performance lever arm *with* subjects)-Matched Subject Design T-Test

There was a significant difference in recorded angular velocity between the Peak Performance skin marker measurements with a subject and Peak Performance lever arm measurements with a subject at 60 and 240 degrees/second. Peak Performance lever arm measurements with a subject recorded higher velocities with the difference between recordings increasing with higher velocities (See Table 6). There was no correlation between variables at 150 and 240 degrees/second. However, there was a significant negative correlation at 60 degrees/second.

Angular Velocities of PPSEG (Peak Performance lever arm *with* Subjects) vs. PPSEG(Peak Performance lever arm *without* subjects)-Single Sample T-test

There was a significant difference in angular velocity between the Peak Motus Motion Analysis with and without a subject at 60 and 150 degrees/second. The PPSEG lever arm without subjects recorded higher velocities at each speed (See Table 7).

Angular Velocities of KC (Kin-Com *with* subjects) vs. KC (Kin-Com *without* subjects) Single Sample T-test

There was no significant difference in angular velocity between the Kin-Com Isokinetic Dynamometer with and without a subject at 60, 150, and 240 degrees/second (See Table 8).

Table 5. Angular Velocities of PPSEG (Peak Performance lever arm measurements *with* Subjects) vs. KC (Kin-Com *with* subjects) Matched Subject Design T-Test

Variable		Descriptives			T-Test			Conditions			
Unit	Velocity	n	mean	SD	df	t	P	Mean	values for 95% CI of the difference	R	p
KC with	60	5	58.73	.410	4	-2.31	.069	-1.07	-2.26 to .122	-.105	.844
PPSEG with	60	5	59.80	1.02	4						
KC with	150	4	147.69	2.41	3	-4.67	.010*	-3.66	-5.84 to -1.48	.689	.198
PPSEG with	150	4	151.36	1.45	3						
KC with	240	4	223.83	3.18	3	-9.66	.001*	-13.45	-17.32 to –9.59	-.988	.002
PPSEG with	240	4	237.28	5.19	3						

*significant difference between pairs at $\alpha \leq .05$

Table 6. Angular Velocities of PP (Peak Performance skin marker measurements *with* Subjects) vs. PPSEG (Peak Performance lever arm *with* subjects)-Matched Subject Design T-Test

Variable		Descriptives			T-Test			Conditions			
Unit	Velocity	n	mean	SD	df	t	P	Mean	values for 95% CI of the difference	r	p
PP with	60	5	54.84	3.04	4	-2.77	.050*	-4.63	-9.27 to .005	-.988	.002
PPSEG with	60	5	59.47	.698	4						
PP with	150	4	131.31	20.69	3	-1.93	.150	-19.59	-51.96 to 12.78	.320	.680
PPSEG with	150	4	150.90	1.20	3						
PP with	240	4	214.65	12.03	3	-3.51	.039*	-21.88	-41.74 to –2.02	.155	.845
PPSEG with	240	4	236.53	5.67	3						

*significant difference between pairs at $\alpha \leq .05$

Table 7. Angular Velocities of PPSEG (Peak Performance lever arm measurements *with* Subjects) vs. PPSEG (Peak Performance lever arm *without* subjects)-Single Sample T-test

Variable		Descriptives			T-Test			Paired Differences		
Unit	Velocities	n	mean	SD	Df	t	P	mean	values for the 95% CI of the difference	
PPSEG with	60	5	59.80	1.02	4	-3.95	.011*	-1.64	-2.71	-.573
PPSEGwithout	60	5	61.44		4					
PPSEG with	150	4	151.36	1.45	3	-2.79	.049*	1.45	-3.62	-.001
PPSEGwithout	150	4	153.17		3					
PPSEG with	240	4	237.28	5.19	3	-1.29	.265	5.19	-9.44	3.44
PPSEGwithout	240	4	240.28		3					

*significant difference between pairs at $\alpha \leq .05$

Table 8. Angular Velocities of KC (Kin-Com *with* subjects) vs. KC (Kin-Com *without* subjects)-Single Sample T-test

Variable		Descriptives			T-Test			Paired Differences		
Unit	Velocities	n	mean	SD	Df	T	p	mean	values for the 95% CI of the difference	
KC with	60	5	58.73	.410	4	2.41	.061	.403	-.027	.832
KC without	60	5	58.33		4					
KC with	150	6	147.73	2.16	5	-2.17	.073	-1.77	-3.77	.227
KC without	150	6	149.51		5					
KC with	240	6	223.37	3.59	5	-1.20	.276	-1.62	-4.94	1.69
KC without	240	6	225.00		5					

*significant difference between pairs at $\alpha \leq .05$

Angular Velocities of KC (Kin-Com *without* subjects) vs. PPSEG (Peak Performance lever arm *without* subjects)- Single Measurement Comparison

With increasing angular velocities, the difference of means between the Kin-Com Isokinetic Dynamometer and the Peak Motus Motion Analysis without subjects increased (See Table 9).

Table 9. Angular Velocities of KC (Kin-Com *without* a subject) vs. PPSEG (Peak Performance lever arm *without* subjects)- Single Measurement Comparison

Variable		Descriptives		
Unit	Velocities	N	mean	mean difference
KC without	60	1	58.33	3.11
PPSEG without	60	1	61.44	
KC without	150	1	149.51	3.66
PPSEG without	150	1	153.17	
KC without	240	1	225.00	15.28
PPSEG without	240	1	240.28	

CHAPTER V

DISCUSSION

Research question 1: What is the angular velocity accuracy of the Peak Motus 2000 compared to the Kin Com at 60, 150, and 240 degrees per second?

Analysis of the data between the Kin-Com and the Peak Performance lever arm with a subject shows a significant difference in angular velocity at 150 and 240 degrees/second. The Peak Performance overestimated the set angular velocities when compared to the Kin-Com with a subject at all speeds. Further analysis of this data proved that there was no correlation between the machines with subjects. Data was unable to be correlated secondary to the comparisons of the low standard deviation values for the Kin-Com and the high standard deviations for the Peak Performance. The lack of correlation brings into question the research protocol. There may be some error in the collection or digitization process. More subjects should be run to confirm or refute this theory.

Without subjects, the Peak Performance lever arm overestimated angular velocities at all speeds when compared to the Kin-Com without subjects. The mean differences between the machines increased as the angular velocity increased with and without subjects. This corresponds to the experiment performed by Selfe[4], in which the Peak 5 showed a trend towards overestimating velocity when compared to the Biodex isokinetic dynamometer. Selfe's [4] study showed that the Peak 5 was most accurate at angular velocities less than 150 degrees/second, which corresponds with this study. In Selfe's [4] study the mean differences increased as angular velocities increased, with the largest mean difference being 2.3 degrees/second at 150 degrees/second. In this study the same occurred, but the largest mean difference was 15.28 degrees/second at a speed of 240 degrees/second. The mean difference in this study at 150 degrees/second was 3.66, which was larger than what Selfe[4] had found in his study. Possible differences between Selfe's[4] data and the data from this study include: Selfe[4] only analyzed one repetition at each speed, where an average of three repetitions was analyzed in this study and Selfe[4] used different brands of equipment including the Peak 5 (an older model than the Peak Motus 2000). Experiments from Schrag and Rodgers[17] also confirmed that the Peak 5 is most accurate when filming movement at slower speeds.

Research question 2: How does use of a subject affect angular velocity of the Kin-Com and/or the Peak Motus 2000 system?

We found there was only a small difference in angular velocity measurements with and without subjects. Testing between the three speeds yielded no greater than a 3.0 mean difference in degrees/second. This data indicates the Peak Performance is accurately measuring angular velocity at 240 degrees/second trial. Without subjects, the Peak Performance lever overestimated velocities compared to with subjects. The difference between the means grew larger with increased speed. This may imply that subject's weight of their limb at slower speeds may decrease the angular velocity of the lever arm. There was no significant difference between angular velocity measurements of the Kin-Com with and without subjects at all speeds. This data shows that the Kin-Com is reliable both with and without a subject. Kin-Com data collected in this study corresponds to the study conducted by Mayhew et al[7]., in which the Kin-Com's angular velocity measurements were found to be highly reliable and valid.

Research question 3: How may skin marker placement affect velocity measurements?

Initial analysis of the data shows a significant difference in angular velocity at 60 and 240 degrees/second. Lever arm angular velocity measurements were higher at all speeds. The skin marker data proved to be the least accurate and had the greatest error/skin marker deviation. Further analysis of this data proved there was no correlation between Peak Performance skin marker measurements and Peak Performance lever arm with a subject. Data was unable to be correlated secondary to the comparisons of the low standard deviation values for the Peak Performance lever arm and the high standard deviations for the Peak Performance skin marker displacement. The Peak Performance skin marker measurement had high standard deviations possibly due to lack of knee restraints of the subjects, which would make this data unreliable. We believe that it is due to lack of knee restraints because a strict protocol was followed with one tester placing all markers on subjects, which were not removed between trials, errors in placement and reapplication of markers were eliminated.[5] In an ideal test, there should be no significant difference between these values.

Although researchers followed a protocol to avoid examiner related variability, the variance in our standard deviation values identified error. Initially, data was analyzed using the complete data set of each plantarflexion/dorsiflexion cycle. This data which included acceleration and deceleration angular velocity values showed large differences in standard deviation values between the machines. We decided to further analyze the data by looking only at the middle fifty percent of each cycle and excluding the first and last quartile of data, which allowed us to eliminate acceleration and deceleration values. The same result of high variance in standard deviations was found.

The compiled standard deviation values during testing with a subject from lowest to highest are Kin-Com, Peak Performance lever arm and Peak Performance skin marker measurement. This indicates that the Kin-Com is highly accurate when measuring joint angular velocity. This also indicates that some factor caused skin marker angular velocity measurements to be inaccurate. This also shows us that since the PPSEG values come from points placed on the Kin-Com's lever arm, since no skin movement can occur at these points, this should be the most accurate data when compared to the Kin-Com data. Standard deviations for all the compiled Peak skin marker angular velocity trials at 60, 150, and 240 degrees/second are as follows in degrees/second; 3.04, 20.69, 12.03. Standard deviations for all the compiled Peak lever arm angular velocity trials at 60, 150, and 240 degrees/second are as follows; .698, 1.20, 5.67. Standard deviations for all the compiled Kin-Com angular velocity trials at 60, 150, and 240 degrees/second are as follows; .410, 2.41, 3.18.

The standard deviation values also increase as the speed of the device is increased. The difference in the machines is that the Kin-Com standard deviation increases less than the Peak lever arm segments which is less than the Peak skin markers. The Kin-Com has a higher sampling rate and more accurate data than the Peak lever arm which has a lower sampling rate with no skin marker movement. The Peak skin markers have a low sampling rate and skin and body movement, which makes it the least accurate.

It also became evident from our data collection that the Peak Performance over-estimated velocity when compared to the Kin-Com. The velocity measurements from the Peak also became increasingly larger as the speed was increased.

Limitations

The main limitation of this study was that a small sample size was used, which leaves little room for error. Another limitation was that there was a high degree of variability with Peak Performance skin marker angular velocity measurements when compared to Kin-Com or Peak Performance lever arm angular velocity measurements. Possible sources of this error are excess knee movement of the subjects due to lack of restraints, movement out of the standard test position, skin marker placement by the tester, and skin marker movement during the trials. Another limitation is the fact that the Kin-Com needs to accelerate and decelerate to reach its set angular velocity, which provides a great deal of variance when statistically analyzed. If this study were to be conducted again, a larger sample size would be utilized. Also, subjects would use a knee restraint during all trials in order to better secure his or her lower limb. It would be ideal if the sampling frequencies between the two machines were the same. Changing these factors may help increase the correlation between the two machines.

CHAPTER VI

CONCLUSION

Data that compared Kin-Com angular velocity measurements with and without subjects showed no significant difference at any of the tested speeds. Therefore, this study confirms that the Kin-Com isokinetic dynamometer provides reliable angular velocities, as stated by other researchers. The data was analyzed, and conclusions were drawn with the previous statement in mind.

Data from this study has shown that without the use of subjects there is no significant difference in reported angular velocity between the Kin-Com and Peak Motus 2000 at 60 degrees/second. However, there is a significant difference in reported angular velocity between the Kin-Com and Peak Motus 2000 at 150 and 240 degrees/second without subjects. This study correlates with others by showing that motion analysis systems are most accurate at determining angular velocity at lower speeds.

It was found that skin marker error, whether due to biomechanical movement of the subject or musculoskeletal movement beneath the skin's surface caused Peak Performance data with subjects to decrease in accuracy as angular velocity increased. Peak Performance skin markers showed the greatest increase in standard deviation values as angular velocity was increased.

Clinical Implications

This study shows that the Kin-Com angular velocity settings are reliable, providing an appropriate clinical tool when the speed of motion must be precise. This becomes increasingly important during acute injury, post-operatively, assessing the need for surgical intervention, or when biomechanical correction of an athletes performance is critical for success. This study also shows the importance of following precise protocol and control of the environment, as small variations can cause large error. It is also important to remember that motion analysis measurements may be over-estimated, which may prove to be detrimental to patients evaluated by such machines. The Peak 2000 motion analysis system is a reliable tool for evaluation of movement at lower angular velocities.

APPENDIX A

INFORMATION AND CONSENT FORM

TITLE: Reliability and validity of angular joint velocity using Peak Motus 2000® Motion Analysis and Kin-Com® Isokinetic Dynamometer

You are being invited to participate in a study conducted by Dave Relling, a physical therapy instructor at the University of North Dakota, Mark Wagner and Meaghan Kuklok, physical therapy students at the University of North Dakota. The purpose of this study is to determine the accuracy of the speed of ankle joint motion using a videotape and computer based motion analysis system (Peak Motus 2000) when measured against known values. A machine will move your ankle up and down at a fixed speed to produce the known values (Kin-Com). The results will attempt to provide information on the accuracy of the equipment with and without use of subjects, therefore establishing a confidence interval for clinical use. Only normal, healthy subjects will be asked to participate in this study. **If you have a tape allergy or have fractured, sprained or strained your ankle within the past year or are not between the ages of 18-30, you are not eligible to participate in this study.**

The study will take approximately forty-five minutes of your time. You will be asked to report to the University of North Dakota Physical Therapy Department at an assigned time. You will then be asked to change into gym shorts (that will be provided for you) in a private changing room for the experiment. We will first record your age, gender, height and weight for future statistical analysis. During the experiment, we will be recording movement speed of your right ankle with the use of video equipment. Your right ankle movement will be collected on video- tape and digitally transferred to a Peak Motus 2000 computer system. All future representations of the data will be computer generated stick figures with no use of the original video image. Data will be collected in a confidential manner and will be reported without any subject identifying information. Names will be not be used for any reason in this study. Subjects will be assigned code numbers to ensure strict confidentiality.

You will be asked to allow us to place three reflective markers on your skin surrounding the right ankle joint with double-sided tape. If you have excessive hair on your right ankle, it will be removed with an electric shaver by Mark Wagner or Meaghan Kuklok. You will then be asked to perform a warm-up of 20 repetitions of non-weight bearing ankle motions. Upon completion of the warm-up, you will be placed on the Kin-Com Isokinetic Dynamometer and taken through six repetitions of different speeds of passive motion (total time approximately *30 minutes*). The machine will guide you through small motions at slow, medium, and fast *speeds* that will require no exertion on your part. You will be given a short rest period of approximately 1 minute between trials.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record angular joint velocities using motion analysis, we will be placing reflective markers on the skin of your right lower leg and foot. Shaving of the hair from the area where the reflective marker is placed may be necessary. These reflective markers only record information from joint angles, they do not stimulate the skin. The exercises you will be taken through are passive; therefore, no muscle exertion is required. You will benefit as a subject by gaining the experience of participating in an experimental procedure.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the

University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigators involved are available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dave Relling or any of the other investigators at (701) 777-2831. A copy of this consent form is available to all participants in the study. Signed consent forms will be kept by Dave Relling in the University of North Dakota Physical Therapy Department for three years.

In the event that this research activity (which will be conducted at the University of North Dakota Physical Therapy Department) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to any member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payer, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION; I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by Dave Relling, Mark Wagner or Meaghan Kuklok.

____

Participant's Signature Date

____

Witness (not the scientist) Date

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

Date: March 16, 2000 **Project Number:** IRB-200003-169

Name: Dave Relling, Mark Wagner, Meaghan Kuklok **Department/College:** Physical Therapy

Project Title: Reliability and Validity of Angular Joint Velocity Using Peak Motus 2000® Motion Analysis and Kin-Com® Isokinetic Dynamometer

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on March 17, 2000 and the following action was taken:

☒ Project approved. **EXPEDITED REVIEW** Category No. 4
Next scheduled review is on: March 2001

☐ Project approved. **EXEMPT REVIEW** Category No. ______
No periodic review scheduled unless so stated in the Remarks Section.

☐ Project approved **PENDING** receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. **This study may NOT be started UNTIL final IRB approval has been received.** (See Remarks Section for further information.)

☐ Project approval **deferred. This study may not be started until final IRB approval has been received.** (See Remarks Section for further information.)

☐ Project **denied.** (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature.

Linda M Larson 3/17/00

Signature of Designated IRB Member
UND's Institutional Review Board

Date

cc: Dave Relling, Adivser
Chair, Physical Therapy
Dean, School of Medicine

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

1(1/98)

_X_ EXPEDITED REVIEW REQUESTED UNDER ITEM _4_ (NUMBER[S]) OF HHS REGULATIONS
___ EXEMPT REVIEW REQUESTED UNDER ITEM ___ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Dave Relling, Mark Wagner, Meaghan Kuklok **TELEPHONE:** 701-777-2831 **DATE:** February 2000

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 501 N. Columbia Road, P.O. Box 9037, Grand Forks, ND 58202-9037

SCHOOL/COLLEGE: Medicine **DEPARTMENT:** Physical Therapy **PROPOSED PROJECT DATES:** February 2000-February 2001

PROJECT TITLE: Reliability and Validity of Angular Joint Velocity using Peak Motus 2000® Motion Analysis and Kin-Com® Isokineti(Dynamometer

FUNDING AGENCIES (Include copy of proposal): ___

TYPE OF PROJECT (Check ALL that apply):

_X_ NEW PROJECT ___ CONTINUATION ___ RENEWAL ___ DISSERTATION OR THESIS RESEARCH _X_ STUDENT RESEARCH PROJE(

___ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Dave Relling, MS, PT

PROPOSED PROJECT: ___ INVOLVES NEW DRUGS (IND) ___ INVOLVES NON-APPROVED USE OF DRUG ___ INVOLVES A COOPERATINC INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATION, PLEASE INDICATE THE CLASSIFICATION(S):

[ ] MINORS (<18 YEARS) [ ] PREGNANT WOMEN [ ] MENTALLY DISABLED [ ] FETUSES [ ] PERSONS WITH

[ ] PRISONERS [ ] ABORTUSES [X] UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE ___

IF YOUR PROJECT HAS BEEN\WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S): ___

Status: ___ Submitted; Date ___ ___ Approved; Date ___ ___ Pendir

1. **ABSTRACT:** (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.)

Motion analysis systems have been found to be accurate at measuring angular joint velocities at less than 150 degrees/second. *Newly released motion analysis software*, Peak Motus 2000, has not been assessed for its accuracy. Considering that most human motion occurs at speeds greater than 150 degrees/second, the purpose of this study is to determine the accuracy of the Peak Motus 2000 at speeds ranging from 60-450 degrees/second. The validity of the angular joint measurements recorded by the Peak Motus 2000 will be measured against the Kin-Com Isokinetic Dynamometer. *Literature supports that the angular velocity settings on the Kin-Com are extremely accurate.*

To determine if human subjects will cause differences in the accuracy of angular joint velocity measurements, we will compare the data with and without subjects. Motion analysis is used for functional and sport activities. To accurately assess the validity and reliability of the Peak Motus 2000 system in these situations, human subjects will be required.

Our results will attempt to provide information on the accuracy of the angular joint measurements analyzed by the Peak Motus 2000 during human motion. We will use ankle motions to assess reliability and validity.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary. Attach any surveys, tests, questionnaires, interview questions, examples of interview questions (if qualitative research), etc., the subjects will be asked to complete.)

Subjects

The subject sample will consist of 50 randomly selected *male and female physical therapy students* from the University of North Dakota voluntarily recruited. *Mark Wagner and Meaghan Kuklok will present a verbal overview of the study to the students on 4/20/2000 in the physical therapy department at the University of North Dakota. The subjects must be healthy without existing ankle pathology. It will be expressed verbally to the students that, those who have had ankle surgery, ankle sprains, or ankle musculature strains within the last year are not eligible to participate in the study. Subjects will be asked if they have an existing tape allergy, those with tape allergies are not eligible to participate.* Subjects will be between the ages of eighteen and thirty. All subjects will appear to be in good general health. All participants will sign the appropriate human subject consent form.

Procedure

The study will be conducted in the University of North Dakota Physical Therapy Department. Upon entering the facility, the subjects will be given verbal instructions on the purpose and procedure of the study, and then will be asked to sign a consent form. Any questions that the subject may have will be answered. *The subject will be provided with gym shorts and a private changing room. The subject's height, weight, age, and gender will be recorded for future statistical analysis. Height and weight will be measured with standard devices by Mark Wagner or Meaghan Kuklok. Excessive hair will need to be shaved if it impairs the reflective marker's ability to stick to the skin. The hair will be shaved with an electric razor, similar to a barber shop, by Meaghan Kuklok or Mark Wagner.*

Video analysis will be used to measure angular joint velocity of the ankle during the activity. Reflective markers will be attached to the right ankle joint using double-sided tape. The reflective markers will be placed in identical landmarks for all subjects. Video cameras will be placed around the subject and will film the subject's ankle movements while on the Kin-Com Isokinetic Dynamometer. This will be recorded on videotapes and will be transferred to a computer for analysis. *The video will only record the subject's ankle; therefore, there is no way to identify the subject.* The Peak Motus 2000 motion analysis computer software program is used to interpret recorded video motion to determine angular joint velocity.

The Kin-Com Isokinetic Dynamometer will be set up for an ankle motion protocol. The subject will perform a warm-up of twenty repetitions of active ankle plantarflexion and dorsiflexion in a seated non-weight bearing position. The subjects will be in a seated position and stabilized according to the standard set up as described in the Kin-Com manual. The subject will then be taken through five repetitions each of the following passive speeds: 60, 150, 300, and 450 degrees/second. There will be a one- minute interval between the sets to allow time to adjust the different speeds. Total test time will be approximately *45 minutes* for each subject.

The Kin-Com Isokinetic Dynamometer will then be utilized without subjects and set to passively move through the same speeds, five repetitions. *Reflective markers will be placed on the moveable arm of the Kin-Com in comparable positions to where the markers were placed on the ankle joint when a subject was used. The moveable arm is a steel bar that parallels the subject's right lower leg; the subject's leg is fastened to the arm using Velcro straps.* This test protocol will provide information that will be compared with subject data concerning variability of measurements.

Data collection will consist of measurements of ankle joint velocity from both the Peak Motus 2000 Video Motion Analysis and the Kin-Com Isokinetic Dynamometer. *Statistical analysis will be completed comparing data sets, data will be coded to prevent subject identification and no identifying information will be included in report summaries.*

3. BENEFITS: (Describe the benefits to the individual or society.)

Possible benefits of this study:

1. Attainment of data to support the validity and reliability of the Peak Motus 2000 video motion analysis system.
   - The accuracy of this equipment is crucial when determining angular joint velocities for a variety of patient populations.
   - Literature on past motion analysis equipment indicates that it becomes less accurate at higher speeds, possibly leading to inaccurate analysis of human motion.
   - *Motion analysis is used for analysis of walking in clinical gait labs in the United States with recommendations for surgical interventions.*

2. Determining the accuracy of the equipment with and without use of subjects, therefore establishing a confidence interval for reliable and valid clinical use.

3. Reliability of reflective skin marker placement when compared to placing reflectors directly on the equipment.

4. *Subjects will benefit by gaining the experience of participating in an experimental procedure.*

4. RISKS: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, debriefing procedures, storage of data for the required three years, final disposition of data, etc.

Physical risks to the subject in this study are minimal. *In the event that this research activity (which will be conducted at the University of North Dakota Physical Therapy Department) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to any member of the general public in similar circumstances. Payment for any such treatment must be provided by the subject and his/her third party payer, if any. Isokinetic testing and video motion analysis equipment pose minimal risk of physical injury to the subjects.* The testing involves passive, normal motions, therefore providing minimal stress to the joint. The warm-up and the steady increase in speeds will also further reduce the risk of injury. *Those with tape allergies will be excluded from the study. The use of an electric barber hair clipper may be required to remove excess hair.*

Data will be collected in a confidential manner and will be reported without any subject identifying information. Names will be not be used for any reason in this study. Subjects will be assigned code numbers to ensure strict confidentiality. Participation within the study is on a voluntary basis therefore the participants are free to withdraw at any time for any reason without prejudice from the Department of Physical Therapy or the University of North Dakota School of Medicine. Data and videotapes will be kept for a minimum of three years after the completion of the study in the University of North Dakota Physical Therapy Department, safely locked. Data and videotapes will be destroyed after three years. Dave Relling will be the only individual with access to the data and videotapes after the completion of the study.

Motion analysis data is collected on video- tape and digitally transferred to Peak Motus 2000 computer system. All representations of the data are computer generated stick figures with no use of the original video image.

A copy of the consent form is attached. Signed consent forms will be kept by David Relling in a locked file for a duration of three years following the completion of the study in the University of North Dakota Physical Therapy department. After three years they will be destroyed.

5. **CONSENT FORM:** Attach a copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

6. For **FULL IRB REVIEW** forward a signed original and fifteen (15) copies of this completed form, including fifteen (15) copies of the proposed consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to the address below. An original and 19 copies are required for clinical medical projects. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency should be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical medical.

Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original, including a copy of the consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to one of the addresses above. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency should be attached to the completed Human Subjects Review Form.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

Principal Investigator ____________________ Date ________

Project Director or Student Adviser ____________________ Date ________

Training or Center Grant Director ____________________ Date ________

(Revised 4/1998)

RELEASE STATEMENT

I hereby give my permission to the University of North Dakota, its agents, successors, assigns, clients and purchasers of its services and/or products, to use my photograph (whether still, motion or television)

Name:

Signed:____

Date:____

Address:_______________________________________

City:____

State and Zipcode:________________________________

REFERENCES

1. Allard P, Stokes IA, Blanchi JP editors. *Three-Dimensional Analysis of Human Movement.* Published by Human Kinetics 1995; Page 111.

2. Trendinnick TJ, Duncan PW. Reliability of concentric and eccentric isokinetic loading. *Phys Ther.* 1988;68:656-659.

3. Peak Performance Technologies, Inc. Web Site. Available at: http://www.peakperform.com/aboutus.htm. Accessed March 16, 2000.

4. Selfe J. Validity and reliability of measurements taken by the Peak 5 motion analysis system. *J Med Eng Technol.* 1998;22:220-225.

5. Robinson ME, O'Connor PD, Shirley FR, MacMillan M. Intrasubject reliability of spinal range of motion and velocity determined by video motion analysis. *Phys Ther.* 1993;73:626-631.

6. Scholz JP, Millford JP. Accuracy and precision of the PEAK performance techonologies motion measurement system. *J Motor Behav.* 1993;25:2-7.

7. Mayhew TP, Rothstein JM, Finucane S, Lamb RL. Performance characteristics of the Kin-Com® dynamometer. *Phys Ther.* 1994;74:1047-1054.

8. Wilson DJ, Smith BK, Gibson JK. Accuracy of reconstructed angular estimates obtained with the Ariel performance analysis system™. *Phys Ther.* 1997;77:1741-1746.

9. Hislop HJ, Perrine JJ. The isokinetic concept of exercise. *Phys Ther.* 1967;47:114-117.

10. Alexander MJL. Peak torque values for antagonistic muscle groups and concentric and eccentric contraction types for elite sprinters. *Arch Phys Med Rehabil.* 1990;71:334-339.

11. Francis K, Hoobler T. Comparison of peak torque values using the Cybex II® and Lido 2.0® isokinetic dynamometer. *JOSPT.* 1987;8:480-483.

12. Farrel M, Richards K. Analysis of the reliability and validity of the kinetic communicator exercising device. *Med Sci Sports Exerc.* 1986;18:44-49.

13. Snow CJ, Blacklin K. Reliability of knee flexion peak torque measurements from a standardized test protocol on a Kin-Com® dynamometer. *Arch Phys Med Rehabil.* 1992;73:15-21.

14. Norkin CO. *Joint Structure and Function: A Comprehensive Analysis.* 2nd ed. Philadelphia, PA: FA Davis Co; 1992:35-36, 40, 107-111.

15. Kelley MJ, Clark WA. *Orthopedic Therapy of the Shoulder.* Philadelphia, PA: JB Lippincott Co; 1995:351-406.

16. Kin-Com: *Clinical Desk Reference.* Chattanooga, Tenn: Chattanooga Group, Inc; 1995.

17. Schrag D, Rodgers MM. *Reliability and accuracy of the peak performance three dimensional motion measurement system.* In Proceedings of the 6th East Coast Clinical Gait Conference; 1990: 137-140. Cited by: Selfe J. Validity and reliability of measurements taken by the Peak 5 motion analysis system. *J Med Eng Technol.* 1998;22:220-225.

18. Bratton CV, Ross EC. Validity and intertester reliability of static joint angle measurements made with the Peak 5 ® motion analysis system. *Phys Ther.* 1994;74:1081.

19. Vander Linden DW, Carlson SJ, Hubbard RL. Reproducibility and accuracy of angle measurements obtained under static conditions with the Motion Analysis™ video system. *Phys Ther.* 1992;72:300-305.

20. Schamhardt HC, vanden Bogert AJ, Hartman W. Measurement techniques in animal locomotion analysis. *Acta Anatomica.* 1993;146:123-129.

21. LaFortune MA, Lambert C, Lake M. Skin marker displacement at the knee joint. In the Proceedings of the 2nd North American Congress on Biomechanics, Chicago. 1992;101-102.

22. Wilk KE, Keirns MA, Andrews JR. ACL reconstruction: a six month follow –up of isokinetic testing in recreational athletes. *Isokin Exerc Sci.* 1991;1:36-43.

23. Prentice WE. *Rehabilitation Techniques in Sports Medicine.* 2nd ed. St. Louis, MO: Mosby-Year Book Inc.; 1994:76-86, 99-106, 193-194.

24. Timm KE, Iglarsh ZA, Richardson JK. *Orthopaedic PT Clinics of North America: Exercise Technologies.* Philadelphia, PA: WB Saunders Co; 1992.