The mechanical and clinical reliability of the kinetic communicator's gravity correction procedure

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Abstract:
The purpose of this study was to determine the reliability of the Kinetic Communicator's (Kin-Com) gravity correction procedure. To determine mechanical reliability, gravity correction was performed at 11 different angles while weights (1.15, 2.30, 3.45 and 4.60 kg) were suspended from the lever arm. Intraclass correlation (ICC) between trials showed that the Kin-Com was able to gravity correct weights with high reliability (R = 0.961-0.999). Gravity correction values from the 11 angles were analyzed with a one-way analysis of variance with repeated measures to determine if differences existed between gravity correction values collected at different angles for each weight condition. Even though reliability was good for each angle, gravity correction values collected near the vertical position differed from the gravity correction values collected at the horizontal position ($P < 05$). Differences decreased as weight increased. To determine clinical reliability, 25 subjects (age = 21.0 years, height = 16.6 cm, weight = 59.8 kg) were also gravity corrected in both the seated and prone positions at six different angles on 2 separate days. Correlation analysis between days showed good reliability (R = 0.83) for both positions when subjects were corrected at the horizontal. Reliability decreased as the lever arm approached vertical. Differences between gravity correction values existed at every angle measured for both positions. Even though the gravity correction was shown to be reliable at positions other than the horizontal, gravity correction should be performed at the horizontal position each time subjects are assessed.

Article:

1. INTRODUCTION

Isokinetic exercise equipment has become increasingly popular within the past decade. Clinicians utilize isokinetic dynamometers for a variety of reasons, including evaluating muscular performance following injury [14,24] or surgery [10], pre-season screening to detect muscular imbalances and joint abnormalities [22], and testing of healthy individuals to examine the relationship between isokinetic parameters and sport performance [2,11,15,17,18,19].

Many of the uses of isokinetic dynamometry require the subject to be tested on only one occasion. However, repeated tests are appropriate in many cases to assess the progress (or lack thereof) of identified parameters over time. The critical issue of any test/retest situation is the reliability of the instrument. Isokinetic dynamometers have been shown to be relatively reliable in a number of studies with reliability coefficients ranging from 0.63-0.96 [8,9,13]. Several factors have been identified which influence the reliability of retest isokinetic measurements, in-

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cluding test velocity and type of contraction [23]. Test protocol was investigated by Harding et al. [9], who found reliability coefficients were consistently lower between occasions, rather than among repetitions, indicating that isokinetic testing should occur on more than one occasion.

Isokinetic testing of various muscle groups is most commonly performed with the subject placed in a gravity-dependent position. Winter, Wells and Orr [26] and Nelson and Duncan [16] recognized that the effect of gravity significantly influenced quadriceps and hamstring torque production and advocated a gravity correction procedure for more accurate interpretation of muscle performance. Correction for the effect of gravity is particularly important when calculating hamstring to quadriceps reciprocal muscle group ratios [1,5,6,21,25].

Since the gravity correction procedure is advocated when testing reciprocal muscle group ratios in gravity-dependent positions, and subjects are commonly tested over time, the reliability of the gravity correction procedure should be investigated. Therefore, the purpose of this study was to determine the mechanical and clinical reliability of an isokinetic dynamometer's gravity correction procedure.

2. METHODOLOGY

2.1. *Subjects*

Twenty-five female subjects (age = 21 ± 1.5 years, height = 166.6 ± 5.7 cm, weight = 59.8 ± 5.0 kg) were recruited for participation in this study. Only healthy subjects, free from history of significant injury or pathology to the right knee extensor and flexor muscle groups were used for assessment. Subjects were screened by verbal interview. All subjects read and signed an informed consent form approved by the University's Human Investigation Committee.

2.2. *Instrumentation*

Gravity correction was assessed using a Kinetic Communicator (Kin-Corn, Chattecx Corp., Chattanooga, TN) isokinetic dynamometer.

2.3. *Procedures*

Mechanical reliability. The mechanical reliability of the Kin-Com's gravity correction procedure was assessed by determining the instrument's ability to measure the force of a known weight over a period of 15 sessions. The grip attachment was placed on the lever arm so that the load cell was 38 cm from the axis of rotation. A mark was made on the middle of the grip to denote where the force was to be applied. Force was applied by suspending known weights (1.15, 2.30, 3.45 and 4.60 kgs) from the grip attachment. Torque measurements were taken within a 150 degree arc so that horizontal (parallel with the floor) was 0 degrees (confirmed by level). When the lever arm was moved above horizontal, the direction was considered positive; below the horizontal was considered negative. The entire test arc was therefore from — 75 degrees to 75 degrees. Eleven specific angles within the arc were used for force measurements: — 75, — 60, — 45, — 30, —15, 0, 15, 30, 45, 60, and 75°. The order in which angles were tested was randomized using a table of random digits [12].

For each trial, the lever arm was positioned to the appropriate angle as determined by the angle indicator on the computer screen. The 1.15 kg wt was suspended from the grip attachment and steadied. Once the resultant torque measurement was recorded, the weight was removed. The

2.3, 3.45 and 4.6 kg weights were then suspended from the grip attachment and steadied so that torque measurements could be recorded. All weight was removed from the grip attachment prior to the next weight being applied. Once measurements were recorded for the four different weights at the first angle, the lever arm was repositioned to the next angle and the process was repeated. A second trial was performed later in the same day using the same testing order. A new order was established for each day's data collection. Data were collected on 15 separate days.

Clinical reliability. The clinical reliability of the gravity correction procedure was examined by determining the instrument's ability to weigh the same limb, placed in the same position, on two different occasions. The right lower extremity of each subject was assessed within a spectrum of joint angles in random order. The spectrum included six angles, ;15 degrees apart, between 0 and 75 degrees of flexion. The reference point for all gravity correction values was the position of the lever arm in space with respect to the horizontal. If the lever arm was above the horizontal, the angle was considered to be positive and if the lever arm was below the horizontal, the angle was negative. Gravity correction was performed in both the seated and prone positions. These positions were used to replicate isokinetic assessment of the quadriceps and hamstring muscle groups from seated and prone positions, respectively. The spectrum of joint angles used to determine clinical reliability while seated was 0, — 15, — 30, — 45, — 60 and — 75 degrees and while prone was 0, 15, 30, 45, 60, and 75 degrees.

Once preliminary information (height, weight, age) had been recorded, subjects were instructed to perform a basic exercise and stretching program. The exercises were designed to prepare the musculature and to minimize passive tension within the muscles that may have influenced the gravity correction value. The program included riding a stationary bike with low resistance for 5 min followed by static, pain-free stretching of the hamstring and quadriceps muscle groups.

Gravity correction in the seated position occured with the hip flexed to approximately 100 degrees. The axis of rotation of the knee was aligned with the axis of rotation of the dynamometer. Each subject was stabilized with a strap secured around the waist and another strap placed proximal to the knee to secure the thigh to the Kin-Com table. The force pad was secured to the anterior aspect of the distal lower leg so that the inferior border of the pad was at the mid-malleolar line.

Once the subject was properly positioned and secured, the gravity correction mode of the Kin-com software (version 3.3) was accessed. Gravity correction values were recorded with the lever arm positioned at six different angles: 0, — 15, — 30, — 45, — 60 and — 75 degrees. The negative sign denoted the fact that the lever arm was positioned at angles below the horizontal. The order of angle at which gravity correction was measured was randomized. To measure the gravity correction value, the lever arm was positioned at the first test angle. Each subject was instructed to completely relax the leg musculature while the force of the limb due to gravity was measured by the dynamometer. Once the torque value was recorded, the procedure was repeated for the remaining test angles. Subjects returned 2-5 days later to repeat the procedure (in the same order) to determine the reliability of the procedure.

Gravity correction was performed in the prone position as recommended by the manufacturer. Each subject was positioned so that the axes of rotation of the knee and the dynamometer were aligned. The force pad was secured to the posterior aspect of the distal lower leg so that the lever arm length was equal to that used during the knee extension assessment. The lever arm was again positioned to angles of 0, 15, 30, 45, 60 and 75 degrees in random order. These angles were positive in sign because the lever arm was positioned above the horizontal. At each angle, subjects were instructed to completely relax the leg musculature while the machine weighed the limb. The procedure was repeated 2-5 days following the initial test session.

2.4. *Statistical analysis*

Analysis of variance was used to determine intraclass correlation coefficients (ICC) for the mechanical reliability measurements. For 15 days, weights were suspended at each angle during two sessions, one in the morning and one in the afternoon. The morning and afternoon torque values were averaged together to provide a torque score for the day. A one-way analysis of variance with repeated measures for 15 days using the four weights as 'subjects' provided the data necessary to calculate the reliability coefficient (ICC). Eleven total coefficients were calculated to account for each of the angles tested. Four separate one-way analyses of variance with repeated measures for angle and days as 'subjects' were used to determine if gravity correction values differed between angles.

Intraclass correlation was also used to determine clinical reliability coefficients. Twenty-five subjects were gravity corrected at six different angles on 2 separate days (test/retest). The 25 pairs of scores provided the necessary data for the 12 coefficients. Two separate analyses of variance with repeated measures for angles were used to determine if gravity correction values differed between angles.

3. RESULTS

Two aspects of mechanical reliability were addressed in this study. The first dealt with the reliability of the Kin-Com's gravity correction mode; specifically, whether or not the gravity correction procedure reliably reproduced torque measurements when the same force was applied at the same point on the lever arm over 15 days. The second issue was to determine if the position of the lever arm significantly influenced the gravity correction value. Regardless of where the lever arm is positioned in space, the computer program calculates and displays the correction value at the horizontal position. Therefore, there should be no significant difference in gravity correction values collected at 11 different angles. To determine clinical reliability, the test/retest recordings of the gravity correction value for 25 subjects were analyzed. Since the gravity correction value was measured at six different angles in both the seated and prone positions, 12 separate reliability coefficients were calculated to cover all position/angle combinations. As with the issue of mechanical reliability, the gravity correction value was calculated to the horizontal position. Therefore, regardless of the angle at which the limb was positioned, the displayed gravity correction value should have been very similar.

3.1. *Mechanical reliability*

Table 1 presents the reliability coefficients for each angle tested. The average overall mechanical reliabil-

Table 1
Intraclass correlation coefficients for mechanical reliability over 15 days

Angle	ICC
75	0.961
60	0.991
45	0.997
30	0.998
15	0.998
0	0.999
—15	0.999
— 30	0.998
— 45	0.997
— 60	0.994
— 75	0.973
Average	0.991

ity was R = 0.991. Reliability varied from R = 0.961 to R = 0.999 depending upon the angle at which the value was collected. Higher reliability was evident around the horizontal position and decreased as the lever arm approached the vertical in either the positive or negative direction. The reliability coefficients for the negative angles (below the horizontal) were collectively higher then for the positive angles (R = 0.992 vs. R = 0.989). The reliability at the horizontal position was R = 0.999, which was higher than the average of either the positive or negative directions.

One-factor analysis of variance for each of the weight conditions indicate that the gravity correction values varied by angle to some degree for all weights tested. Scheffe post hoc analysis showed that significant differences for all four weight conditions occurred as the lever arm approached the vertical position (— 75 or 75 degrees). For weight 1, the 60, 75, — 60 and — 75 degree positions were significantly different than the other angles. For the second weight condition, only the 75 and — 75 degree position differed from the other angles. Differences continued to decrease as weight increased. The weight 3 and weight 4 conditions showed similar results in that only the 75 degree position differed significantly from the other positions.

3.2. *Clinical reliability*

Table 2 presents the test/retest reliability coefficients for the gravity correction values of the 25 subjects measured at six different angles. The angle value is the position of the lever arm in space, rather than the anatomical value or actual degrees of flexion at the knee joint. For the seated position, the force pad was positioned on the anterior aspect of the distal lower leg so that when the lever arm was at the 0 degree position (horizontal), the knee was in slight flexion (6.3 ± 3.3 degrees). For the prone position, the force pad was placed on the posterior aspect of the distal lower leg so that subjects were actually in slight hyperextension (— 2.2 ± 3.4 degrees flexion) when the lever arm was at the 0 degree angle position.

The average of the reliability coefficients was similar for the seated (R = 0.83) and prone (R = 0.83) positions. The highest reliability coefficient for the seated position was at the 15 degree position (R = 0.96), and the lowest was at the 75 degree position (R = 0.45). In general, reliability was better around the horizontal position and decreased as the lever arm approached vertical. The reliability values for the prone position did not vary as much between angles as did the values for the seated position. Zero and 45 degrees of flexion displayed the highest reliability coefficient (R = 0.88), whereas the 30 degree position displayed the lowest coefficient (R = 0.66).

Analysis of variance for differences in gravity correction values collected at the six different angles demonstrated that, for both conditions, all gravity correction values were significantly different depending upon where the lever arm was positioned in space.

4.DISCUSSION

4.1. ***Mechanical reliability***

The major finding of the mechanical reliability portion of this study was that the Kin-Com's gravity correction procedure is very reliable. The instrument was able to reproduce very similar gravity correction values when weights were suspended from the lever arm over a period of several days. These results agree with Farrell and Richards [4] who reported an ICC of 0.999 for static tests of the force measuring system. There was no reason to suspect the Kin-Com would be less reliable when measuring torque in the gravity correction mode than when in the strength assessment mode. However, the reliability of the gravity correction mode should not be assumed based on the findings from a different mode.

A possible factor contributing to such high reliability coefficients is the number of days used for data collection. Intraclass correlation coefficients (ICC) are derived from an analysis of variance. When a one-factor ANOVA with repeated measures model is used, as in this study, the reliability coefficient is calculated using the equation: mean square between minus mean square error divided by mean square between [3]. The resulting value will vary from between 0 and 1, approaching 1 as the error term decreases. Since the mean square is calculated by dividing the sum of squares by the appropriate degrees of freedom, the mean square will decrease as the degrees of freedom increase. Therefore, the more trials used, the smaller the error term becomes. As such, the reliability coefficient will approach 1.

In order to make a comparison with clinical reliability, ICC's for the mechanical data were recalculated using measures obtained on only day 1 and day 3 (Table 3). Even though total degrees of freedom

Table 2
Intraclass correlation coefficients for clinical reliability

Angle	Seated	Prone
0	0.94	0.88
15	0.96	0.87
30	0.95	0.66 .
45	0.92	0.88
60	0.73	0.82
75	0.45	0.85
Average	0.83	0.83

Table 3
Intraclass correlation coefficients for mechanical reliability over 2 days

Angle	ICC
75	0.837
60	0.957
45	0.977
30	0.965

15	0.990
0	0.992
— 15	0.996
—30	0.997
—45	0.909
— 60	0.966
— 75	0.960
Average	0.959

dropped from 59 to 7, the reliability coefficients remained good for all positions tested.

4.2. *Clinical reliability*

The clinical reliability of the Kin-Coin's gravity correction procedure proved to be reasonably good. As expected, the clinical reliability coefficients were not as high as the mechanical reliability coefficients. Gravity correction for knee extension was performed with the subject in a seated position so that the lower extremity moved in an arc below the horizontal. For knee flexion, subjects were positioned prone so that the lower leg moved in an arc above the horizontal. From the seated position, the gravity correction value proved to be highly reproducible when subjects were corrected near the horizontal (R = 0.92-0.96). However, when subjects were placed in the 60 or 75 degree position, the reliability of the gravity correction procedure became unacceptable. The average reliability for the seated and prone positions was identical (R = 0.83). Reliability for knee flexion was acceptable for all positions except for the 30-degree position. We cannot speculate why this position demonstrated the lowest reliability.

4.3. *Angle differences*

All 11 positions of the lever arm provided reliable results mechanically. That is, the gravity correction value produced by a suspended weight at a given angle was highly reproducible over time. The gravity correction value displayed on the screen after completing the gravity correction procedure is the 'weight' (of the limb) at the horizontal position. If a limb is weighed for gravity correction with the lever arm at the horizontal position, and again with the lever arm at a position other than the horizontal, the two resulting gravity correction values should be equal. Even though the Kin-Com reliably reproduced the gravity correction values of known weights through the entire range of positions tested, the value collected at one position was not necessarily similar to the value collected at another position.

When the lever arm was positioned anywhere between 45 and — 45 degrees, the gravity correction values were not significantly different from the values collected with the lever arm positioned at the 0 degree position. However, as the lever arm approached the vertical in either the positive or negative direction, the gravity correction values varied significantly. Even though the ± 60 and ± 75 degree positions reliably reproduced the gravity correction value over time, the values were consistently different from the values collected at the other positions.

The differences between angles decreased as weight was added. When the 2.3 kg weight was used to provide force, the gravity correction values were similar between the 60 and — 60 degree positions. Only when the lever arm was positioned at either end of the spectrum did the gravity correction differ significantly from those collected at, or near the horizontal position. The trend continued to improve as the weight used to provide force increased.

These findings may have implications as to where gravity correction should be calculated when weighing limbs of less mass. Perrin et al. [20] showed that gravity correction is necessary when assessing strength of the shoulder internal and external rotator muscle groups. Since the mass of the upper extremity is considerably less than the lower extremity, gravity correction values will not be as large. Therefore, gravity correction for assessment of the upper or the lower extremity muscle groups of smaller subjects should be performed near the horizontal position.

For the clinical tests, every position tested provided a gravity correction value significantly different from the value collected at the horizontal. As discussed previously, the differences between angles in the mechanical reliability section decreased as weight increased so that only the 75-degree angle position differed from the horizontal. The difference in results between the mechanical and clinical tests may be explained if the subjects' limbs were not producing as much torque as the weights produced. Table 4 presents the average gravity correction value produced by each weight during the mechanical reliability section and the average gravity correction value for 25 subjects for each test position. Gravity correction values from the seated position fell between the torque values produced by the 2.3 and 3.45 kg weights. Gravity correction values from the prone position fell between the 3.45 and 4.6 kg weights. Therefore, the differences in gravity correction value between angles is not explained by amount of weight.

Table 4
Average gravity correction value produced by experimental weights and subjects

1.15 kg weight	2.8
2.30 kg weight	6.3
3.45 kg weight	9.5
4.60 kg weight	13.1
Subjects seated	8.0
Subjects prone	11.0

There are several other factors that might account for the differences between the mechanical and clinical portions of this study. One major difference between the two portions was the presence of subjects as opposed to weights. Subjects were required to purposefully relax the musculature of the lower extremity during the gravity correction procedure so that the 'dead weight' of the limb would provide the force on the load cell. Without EMG monitoring, it was impossible to absolutely confirm that subjects were, in fact, completely relaxed. The investigator attempted to encourage and confirm relaxation by moving the thigh of the subject to detect tone. If the subject actively pushed into or lifted away from the load cell during the gravity correction procedure, the resultant gravity correction value could be dramatically different from the value measured when relaxed. Because the clinical procedure was dependent upon subject cooperation and the mechanical procedure was not, the clinical reliability was expected to be somewhat less.

Gravity correction values could also have been influenced by the passive tension of the lower extremity musculature. Ford et al. [7] demonstrated that with subjects positioned in the seated position, tension in the knee flexors caused more force to register on the load cell resulting in a higher gravity correction value. A warm up and stretching session was employed before each testing session, but no effort was made to control for the actual amount of flexibility among subjects. Differences in flexibility between days could have accounted for lower reliability coefficients.

Attachment of the weight and the limb to the apparatus was also somewhat different for the mechanical and clinical aspects of the study. For the mechanical reliability portion, weight was suspended from the grip attachment so that force was applied at exactly the same point each time. When subjects were used, the force pad attachment was used so that the pad contacted the anterior aspect of the leg while seated and contacted the posterior aspect of the leg while prone. The pad was secured to the leg by a padded velcro strap which encircled the lower leg. When subjects were positioned to assess knee extension (seated), the weight of the leg was transferred through the strap to the load cell during the gravity correction procedure. The same was true for knee flexion (prone). Depending on the physical characteristics of the strap, it is possible that some force was absorbed by the strap and not transferred to the load cell, causing a greater variability among the gravity correction values.

A final point of consideration is that when subjects were tested, the anatomical position of the leg was not necessarily the same as the lever arm's position in space. Because of the physical makeup of the force pad attachment, when the lever arm was positioned parallel with the floor, the knee was not at anatomical zero. Rather, the knee was usually in some degree of flexion. In this study, 25 subjects were tested on 2 separate days providing 50 opportunities to measure gravity correction. When the lever arm was parallel with the floor, subjects' knees were in an approximate average of 6 degrees of flexion, which might be considered the 'offset angle'. Knee flexion ranged from 0 to 16 degrees. The gravity correction procedure requires the tester to know where the lever arm is in space rather than the position of the leg. If the average value of this offset angle was 6 degrees, the knee would be gravity corrected at 6, 21, 36, 51, 66, and 81 degrees of flexion. The offset angle varied among subjects but was reproduced during the retest so that the average difference between tests was 1 degree. The offset angle for the knee flexion tests was slightly less. The force pad was placed on the posterior aspect of the lower leg, causing the knee to be in slight hyperextension (average: — 2 degrees) when the lever arm was parallel to the floor. The average difference between offset angles from test to retest was less than 1 degree.

5. SUMMARY

The gravity correction procedure was mechanically reliable at all positions tested and clinically reliable at most positions. However, even when the gravity correction procedure was reliable at positions away from the horizontal, it seemed to lack the ability to accurately gravity correct the same limb when measured at two different positions. As such, clinicians are advised to be consistent in selection of joint angle when obtaining gravity correction, and to consider correcting at, or near the horizontal position.

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