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Intramachine and intermachine reproducibility of concentric performance: A study of the Con-Trex MJ and the Cybex Norm dynamometers

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Abstract. *Introduction:* There is minimal information in the literature concerning the intramachine reliability of the new Isokinetic dynamometer Con-Trex MJ, and the intermachine reproducibility of this instrument with the Cybex Norm isokinetic dynamometer.
Objective: The purpose of this study was to provide some insight with regard to the reproducibility of Con-Trex MJ in measuring the knee muscle performance in flexion and extension (concentric) and to compare the variability of measurement between Con-Trex and Cybex Norm.
Methods: 35 (70 legs) male subjects with no previous history of any knee pathology volunteered for the study. Intramachine reproducibility was evaluated by assessing 30 legs twice on the Con-Trex MJ, within 2 to 7 days, at angular velocities of 60°, 180° and 300°/sec. Intermachine reproducibility was evaluated by assessing 40 legs randomly on the Con-Trex MJ and Cybex Norm within 2 to 7 days at 60° and 180°/sec. Coefficient of variation (CV) was used to determine the reproducibility of repeated measurements at $p < 0.01$. Results: Intra: The variability of measurements of Con-Trex for Peak Torque, was 5.19–5.68% for extension and 4.84–7.33% for flexion depending on the angular velocity. This is acceptable for clinical and research studies. Inter: Between the two Isokinetic devices there was a greater CV for Peak Torque ranging 7.28–9.17% for extension and 8.54–15.84% for flexion.
Conclusion: Based on the results of the present study, comparisons of results between the two devices may not be valid. The results for knee flexion and extension measurements at 60° and 180°/sec recorded with Con-Trex were consistently greater than the values recorded with the Cybex Norm.

Keywords: Intramachine, intermachine, reproducibility, reliability, isokinetic, dynamometer

1. Introduction

Establishing the reproducibility of any measuring device is essential before the instrument can be used in data collection. The use of isokinetic devices is increasing world-wide due to their broad range of applications in rehabilitation, training, evaluation of muscle function and data collection using different parameters such as power, work, torque, etc.

Intermachine reproducibility is defined by Bandy and McLaughlin [1] as the measure of the consistency of measurement when using two different devices, and intramachine as the consistency of measurement us-

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ing the same protocol on the same device on the same population on different occasions. Reproducibility of a device such as an isokinetic dynamometer should be assessed under testing conditions and with protocols that are or can be used in the clinic [11].

A number of studies dealt with intermachine reproducibility of isokinetic dynamometers and reported findings regarding the comparisons of the Cybex II and Lido 2.0, the Cybex 6000 and Cybex II and the Cybex Norm and Con-Trex [1,3,5] dynamometers. These studies have focused on the correlation coefficient to express reproducibility, an approach that may be misleading and inappropriate since it is an expression of the relationship between two variables and not their agreement [2,4]. In the present study reproducibility was expressed as the coefficient of variation (CV).

The Con-Trex is a new isokinetic machine and up to date, to the best of our knowledge, no published data exist on its reproducibility or on its comparison with another isokinetic device, other than the one referenced in this paper [3]. The Con-Trex has the potential to perform passive range of motion, concentric and eccentric muscle contraction, isotonic and isometric movements. Also, the dynamometer is equipped with a variety of accessories which render it capable of measuring many other joint systems. The Cybex Norm isokinetic machine which is by far older in terms of commercial availability has similar features and parameters and thus assessment of intermachine reproducibility is possible to determine. If there is no statistical difference between the measurements of the two isokinetic machines then one may extrapolate individual values from one machine to the other.

The purpose of this study was to determine the intermachine and intramachine reproducibility by measuring knee extension and flexion using concentric contraction at angular velocities of 60, 180, 300 °/sec for intramachine (peak torque, work, power) and 60, 180°/sec for intermachine (peak torque).

2. Methods

2.1. Subjects

Fifteen male subjects between aged 23–37 years, volunteered to be tested. The subjects were healthy, had no knee injuries and were moderately active.

For the intermachine evaluation a second group of 20 male football players aged 15–18 years was recruited. All subjects were inexperienced in isokinetic testing.

Table 1
Characteristics of the studied population

	n	Age (years)	Height (cm)	Weight (kg)
Intramachine	15	29.8 (5.67)	177.3 (7.46)	79.6 (10.33)
Intermachine	20	15.8 (0.81)	176.6 (5.14)	63.8 (6.94)

The protocol was approved by the Cyprus Sports Organization, the leading sports authority in Cyprus and all subjects examined by a pathologist and gave their informed consent. Subject characteristics are summarized in Table 1.

2.2. Instrumentation

A Con-Trex Multijoint System (CMV AG) and the Cybex Norm (Lumex, Ronkonkoma) were used in this study. Both have dedicated software which is capable of gravity correction but the calculations differ. On Cybex Norm the gravity is measured only at 45 degrees and the rest of the points of range of motion are calculated. The Con-Trex MJ takes measurements from all the points along the range of motion including the reaction of the stretched tissues at the extremes of the movement. Due to these differences, gravity correction was not included in our measurements so as to exclude a possible parameter that could increase the variability of the data.

An additional difference between the two dynamometers is that the Con-Trex does not allow a change in the direction of movement before the end of the range of motion is reached. Thus, range of motion is constant during the repetitions. Cybex Norm allows a change in the direction of the movement at any point.

2.3. Test protocol

2.3.1. Intramachine reproducibility

For this test, the subjects were asked to perform maximal concentric knee flexions and extensions at isokinetic angular velocities of 60, 180, and 300 °/sec. Prior to data collection each subject warmed up for 5 minutes on a cycle ergometer using low resistance and moderate speed. The muscle contraction variables measured were peak Torque (pT), peak work (W) and power (P). Subjects were tested on two separate occasions 7 days apart. In each session the left knee was always tested first. Each test consisted of a trial phase of 10 continuous concentric flexion and extension cycles at each of the aforementioned angular velocities. A rest of 1 min was given before the testing of the four maximal repetitions was executed. A rest period of two minutes was allowed before the next angular velocity test.

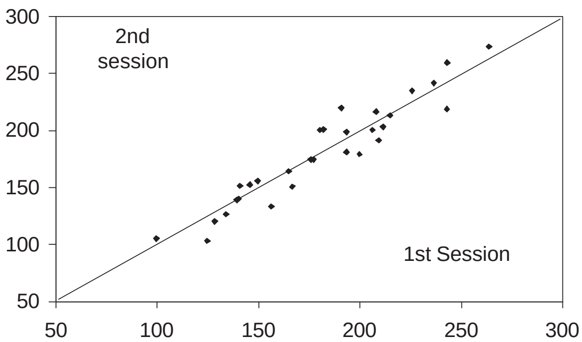

Fig. 1. Extension peak Torque measured in two sessions at 60°/sec with line of equality.

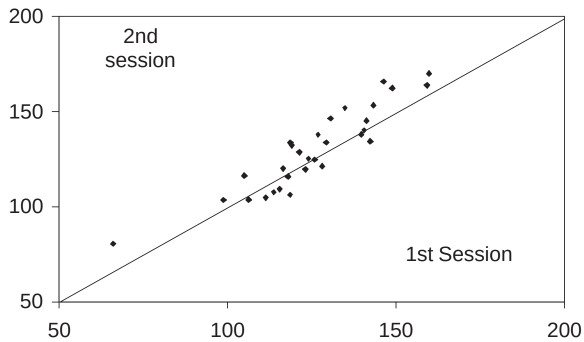

Fig. 2. Flexion peak Torque measured in two sessions at 60°/sec with line of equality.

2.3.2. Intermachine reproducibility

For this test, the subjects were asked to perform concentric knee flexions and extensions at isokinetic angular velocities of 60 and 180°/sec. Subjects were tested in random order approximately one week apart on each isokinetic dynamometer. We tried to perform our measurements the same day of the week in order for subjects to perform the same training the day preceding the test without altering their normal training routine. The same protocol was followed as in intramachine testing.

The muscle contraction variable of interest in this study was PT. Work and Power were not collected because of the differences at the end stops that exist between Cybex and Con-Trex. The measurements of Work and Power are range of motion dependent and the end stops vary between the two isokinetic dynamometers, causing a potential confounding variable.

2.3.3. Positioning

Subjects sat with the hips at 80 degrees flexion. The axis of rotation of the dynamometer was aligned with the anatomical axis of the knee. The thigh was stabilized with a nylon Velcro strap. The resistance pad at the end of the lever arm was positioned one finger width above the lateral malleolus. The subject's upper body was stabilized with the standard x-shaped straps of the dynamometer chair. During the first session the exact positions of all adjustments for each subject were recorded to ensure a placement as consistent as possible in future sessions. The ROM was set at 0 degrees extension to 90 degrees flexion.

2.4. Data analysis

The reproducibility of the repeated measurements was expressed as the pooled coefficient of variation (CVp):

$CVp\% = 100\sqrt{\Sigma di^2/2n}/\overline{x}$ where di is the difference between two results in each individual, n is the number of legs and $\overline{x}$ is the mean obtained from all subjects.

The coefficient of variation for each individual (CVi) was also calculated:

$CVi\% = 100\sqrt{(1/2)di^2}/\overline{x}i$ where di is the difference between two results in each individual and $\overline{x}i$ is the mean of the two results.

Medians and 10th and 90th percentiles (80% central range) of CVi were calculated.

CVp is an indication of the mean variation of the whole sample. CVi and CVi 80% central range give more information about the distribution of the variation [9].

Pairs of strength variables were compared using the Student t-test. P-values of 0.01 or less were considered statistically significant. For the evaluation of the agreement between the two measurements the line of the equality and the difference against mean [2] were plotted.

3. Results

3.1. Intramachine reproducibility

Means and standard deviations (SD) for knee flexion and extension pT, W and P at the various velocities are shown in Table 2. The pTs between two sessions for a given muscle group and velocity were not significantly different ($p > 0.01$). Figures 1 and 2 show the line of equality between the two measurements at 60°/sec extension and flexion. There is a trend for better results at the second session due to prior exposure which did not reach statistical significance. In Table 3, the intramachine coefficient of variation (CVp) for pT did not

Table 2
Intramachine Mean values

	peak Torque Nm (SD)			Work Joules (SD)			Power Watt(SD)		
	1st Session	2nd Session	t	1st Session	2nd Session	t	1st Session	2nd Session	t
60°/sec									
Extension	181.4 (40.5)	180.9 (44)	*	181.8 (40.7)	182.4 (45.2)	*	112.8 (25.2)	114.9 (28.7)	*
Flexion	125.7 (19)	129.8 (21.6)	*	135.6 (20)	139.7 (23.4)	*	84.7 (12.9)	88.2 (15.2)	*
180°/sec									
Extension	140.1 (23.8)	143.3 (27.3)	*	159.7 (29.1)	160.7 (35.4)	*	218.6 (40.3)	221.4 (47.5)	*
Flexion	112.1 (19.3)	114.7 (19.3)	*	126.7 (21.3)	130.8 (22.5)	*	175.3 (29.9)	181.2 (31.6)	*
300°/sec									
Extension	126.7 (29.6)	125.7 (32.2)	*	145.1 (35)	146.8 (40.8)	*	250.2 (63.3)	251.5 (74.7)	*
Flexion	107.2 (20.8)	108.1 (18.2)	*	120.1 (21.5)	122.8 (22)	*	207.7 (37.4)	212.4 (39.4)	*

*: Non significant $p > 0.1$.

Table 3
Intramachine Coefficient of variation

	peak Torque			Work			Power		
	CVp	Cvi	Cvi range	CVp	Cvi	Cvi range	CVp	Cvi	Cvi range
60°/sec									
Extension	5.19	3.61	0.42–7.78	6.75	4.85	1.61–9.77	7.04	4.75	0.59–12.02
Flexion	5.34	4.05	0.89–8.30	5.87	3.65	0.31–9.45	6.30	4.72	0.95–9.14
180°/sec									
Extension	5.24	4.16	0.93–7.57	6.13	5.28	1.17–10.04	6.25	5.33	0.94–10.30
Flexion	4.84	3.44	1.15–8.03	5.75	4.21	0.94–8.31	6.74	4.41	1.03–12.28
300°/sec									
Extension	5.68	4.87	0.59–9.57	5.87	2.59	0.45–10.53	6.07	3.58	1.33–11.25
Flexion	7.33	5.66	1.16–10.28	6.33	5.29	1.52–8.83	6.82	4.88	2.75–10.28

show a great difference (4.84–5.34%) between the three angular velocities for flexion and extension except for flexion at 300°/sec (7.33%). Work and Power results had a greater variability than peak Torque (Work 5.35–6.75%, Power 6.07–7.04%). Figures 3 and 4 show the difference of the results of the two sessions against their mean for extension and flexion at 60°/sec. Most of the measurements are within two standard deviations.

3.2. Intermachine reproducibility

Figures 5 and 6 show the line of equality between the two dynamometers at 60°/sec extension and flexion. There was no obvious relation between the difference and the mean which is shown in Figs 7 and 8 for extension and flexion at 60°/sec. Table 4 presents the intermachine mean peak torque values at 60° and 180°/s for extension and flexion. There was a significant difference ($p < 0.01$) in flexion at 60°/sec and in extension and flexion at 180°/sec. The results of the inter-machine CV are presented in Table 5 for extension and flexion at 60 and 180°/sec. The CVp were high for both angular velocities and movements, ranging from 7.28% to 15.84%. The 90th percentile of the individual CVi ranged from 11.04%, for extension at 60°/sec to 21.4%, for flexion at 180°/sec.

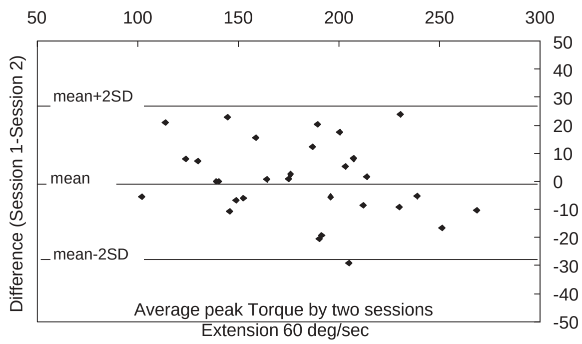

Fig. 3. Difference against mean for extension at 60°/sec (Session 1 – Session 2).

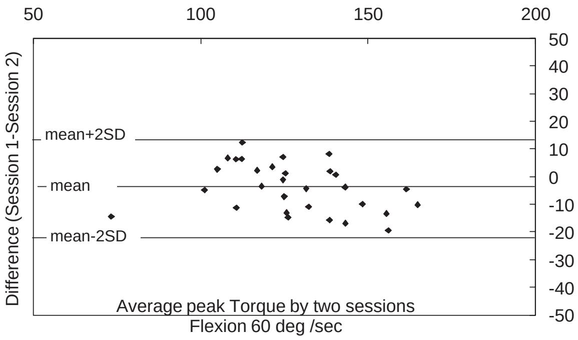

Fig. 4. Difference against mean for flexion at 60°/sec (Session 1 – Session 2).

Table 4
Intermachine Mean peak torque values

	peak Torque Nm (SD)		
	Cybex Norm	Con-trex MJ	t-Test
60°/sec			
Extension	172.7 (24.2)	168.8 (26.8)	*
Flexion	121 (24.2)	127.6 (23.4)	+
180°/sec			
Extension	121.4 (17.6)	132.8 (19.7)	+
Flexion	98.1 (17.7)	115.5 (17.7)	+

*: Non significant $p > 0.05$.
+: Significant $p < 0.01$.

Table 5
Intermachine Coefficient of variation

	peak Torque		
	CVp	Cvi	Cvi 90% range
60°/sec			
Extension	7.28	6.33	1.29–11.04
Flexion	8.54	5.58	2.18–15.30
180°/sec			
Extension	9.17	5.03	1.59–14.89
Flexion	15.84	14.15	2.04–21.40

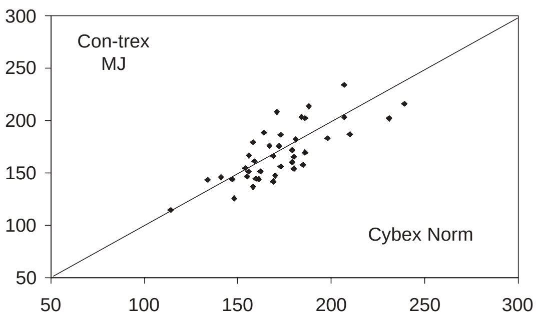

Fig. 5. Extension peak Torque measured with Cybex and Contrex at 60°/sec with line of equality.

4. Discussion

The purpose of this study was to evaluate the reproducibility of the Con-Trex isokinetic dynamometer

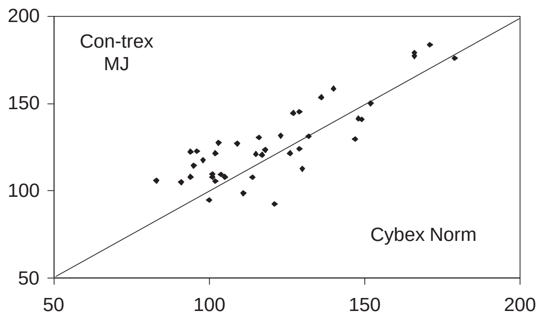

Fig. 6. Flexion peak Torque measured with Cybex and Contrex at 60°/sec with line of equality.

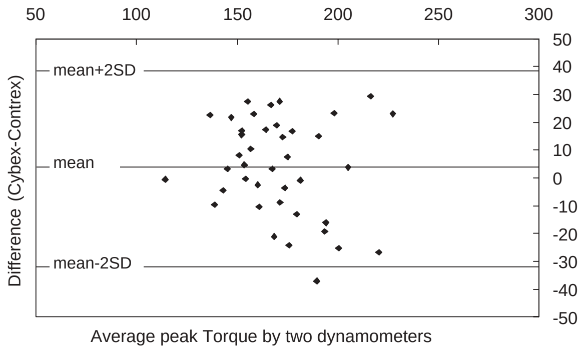

Fig. 7. Difference against mean for extension at 60°/sec (Cybex-Contrex).

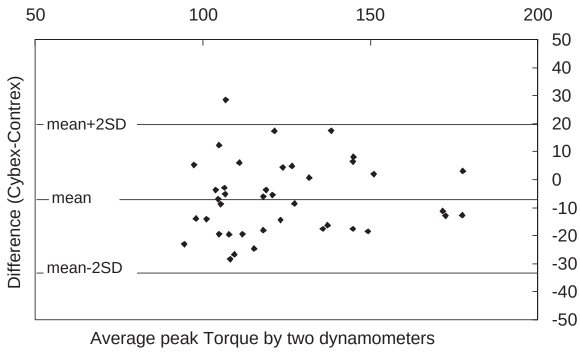

Fig. 8. Difference against mean for flexion at 60°/sec (Cybex-Contrex).

and to determine how the data from this dynamometer correlated with those acquired from the Cybex Norm.

4.1. Intramachine reproducibility

The results of the repeated measurements showed no statistically significant difference for all the angular velocities (60, 180, 300°/sec) and for all the parameters (Torque, Work, Power). With the protocol used, no statistically significant learning effect seemed to emerge. A variation in both negative and positive directions was observed in the raw scores of extension movement and there was a non significant trend towards a positive direction in the flexion movement. This may be explained by the enhanced motivation of the subjects, the "high demand" verbal encouragement given to them by the testers and by the adequate "learning phase" of 10 submaximal repetitions given 1 minute prior to the actual data collection phase. Our findings were similar to those of Madsen [9] and Steiner et al. [11], who reported no muscle performance gain for any of the three variables studied for isokinetic knee flexion and extension.

Coefficient of variation scores ranging from 2.9% to 29% were reported for peak Torque during knee extension over separate days [6–9]. Gleeson and Mercer [6], have measured isokinetic strength of the knee, 5 days apart in 10 healthy men and found a 2.9% CV for peak torque at extension and a 5.0% CV at flexion. Madsen [9], has found short term CV at 30 and 240°/sec for knee extension to be 5.2% and 7.8% respectively, which are in agreement with those found in the present study. Heinonen [7], determined the CV for knee extension to be approximately 6% in sedentary middle aged women.

In the present study, CVp ranged from 4.84 (flexion, 180°/sec) to 7.33% (flexion, 300°/sec) for the extension at 60°/sec. The critical difference between two results that would be statistically significant can be calculated if the Cvp is multiplied by 2.77 ($1.96\sqrt{2}$) [10]. We believe that while using the present system and protocol, a test – retest difference of 14–20% is the least discriminatory capacity in terms of identifying gross dynamic muscle insufficiency. Thus, when a lesser difference is exhibited by an individual, this may not be due to actual strength change but due to measurement errors and the day-to-day variability in performance. This is in agreement with Dvir [4] who suggested that "unless a 20% difference is found on retesting, no real change is indicated".

4.2. Intermachine reproducibility

There is only one previous study comparing these two isokinetic devices [3]. However the sample size used was small ($n = 9$). Our results agree with this previous study, that the differences at extension at 60°/sec are not statistically significant. With the sample size used in the present study statistically significant differences emerged at 60 and 180°/sec leg flexion and at 180°/sec leg extension. A plot of the difference between the two dynamometers against their mean is displayed in Figs 3 and 4 for extension and flexion at 60°/sec. According to Bland and Altman how far apart measurements can be is a question of judgment [2]. If the provided differences within d±2SD are not clinically important we could use the two measurements interchangeably. In this study, the magnitude of d±2SD for extension at 60°/sec was −31 to 39 Nm. These differences are so wide that they make the extrapolation of the "normative data" or individual values from Cybex to Con-trex clinically irrelevant.

5. Conclusions

This study showed that Con-trex is a reliable machine for knee flexion and extension measurements at angular velocities of 60, 180 and 300°/sec with the least variability on peak torque of knee extension at 60°/sec. There is a need for further studies with greater samples in order to determine the reproducibility of other parameters such as range of motion at peak Torque and total Work for endurance test. Statistically significant differences emerged between the data acquired using Con-trex and Cybex Norm. These differences are clinically important and reflect the well established knowledge that no two individual makes of isokinetic dynamometers yield compatible test findings.

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