Isokinetics and Exercise Science 11 (2003) 37–43
IOS Press

Comparative study of two isokinetics dynamometers: CYBEX NORM vs CON-TREX MJ

T. Cotte* and J.-M. Ferret
Centre de Médecine du Sport de Lyon Gerland, 23 rue Félix Brun, 69007 Lyon, France
Tel.: +33 4 72 76 00 30; Fax: +33 72 76 00 40; E-mail: thierry.cotte@fnac.net

1. Introduction

In the majority of peripheral joints (ankle, knee, hip, elbow, wrist . . .), the contraction of a muscular group produces a circular movement of the bony lever around the center of rotation represented by the joint.

In 1967, Hislop end Perrine [6] invented the first isokinetic dynamometer which is dedicated to quantify the force moment (or torque) express by the contraction of a muscular group during a circular movement. Today, the market is shared between several constructors. Nevertheless, even if their vocation is to quantify a force movement, users are often disappointed by not being able to reproduce values between two machines. Differences of the subjects installation may be an explanation for those gaps [5,7].

CYBEX NORM and CON-TREX MJ are two isokinetic dynamometers distributed throughout the world. Thanks to their technical possibilities, they can deal with maximal intensity measurements in high level sportsmen [1,2,7] as well as with the very weak intensities you find in patients affected with spasticity [3,4, 11].

The purpose of this study is three-fold:

- To check that the two machines measure the same moment of force when they are put onto a known load, on the same angular sector and at the same speed.
- Nearby high level sportsmen, check for two similar installations, maximal torques are identical between the two machines for comparable angular sectors and speed.
- To compare those sportsmen's subjective sensations after having tried the two machines.

*Corresponding author.

ISSN 0959-3020/03/$8.00

2. Method and material

First test, the two machines have been compared using certified additional loads (protocol 1). In a second, machines have been compared via high level sportsmen's performance (protocol 2), and a subjective questionnaire has been submited to those same subjects (protocol 3).

2.1. Protocol 1

Practical approach

A known and certified additional load was put onto on each engines via a lever of 0.5 meter.

Angle

The movement goes from a horizontal position to a vertical one, that is to say a 90°.

ROM in order to avoid uncontrolled acceleration, the exercise starts at 90°, then the machine lifts the load to a horizontal position at $5^\circ.s^{-1}$ and then release it.

Table 1
Characteristics of the studied population

	Sex	Age	Weight (kg)	Height (cm)
Studied population	3 women 6 men	26.78 ± 4.18	71.33 ± 10.54	175.89 ± 6.92

Load

The exercises have been realized with 2 different and certified loads: 25 lbs and 50 lbs.

Speed

Too fast speeds have not been used because of the kinetic energy generated during the acceleration phase which is too high and which could have altered the test. Therefore, it has been realized with a $5^\circ.\mathrm{s}^{-1}$ speed.

Repetition

20 repetitions per load.

Measure

Of the maximal torque.

Statistics

Results gained for each load have been averaged to compare one machine to the other by a Student's t test. The threshold of significance was $P < 0.01$.

2.2. Protocol 2

2.2.1. Population

Nine high level sportsmen voluntary participated the study. All the subjects were active sportsmen (soccer, rugby, sprint), with training 4 to 8 times a week. Characteristics of the studied population are presented in Table 1.

2.2.2. Evaluation on isokinetic dynamometer

Bilateral test on the knee joint on each machine

Five subjects started on the CYBEX NORM machine, four on the CON-TREX MJ. Each subject always started with the same limb side on the 2 machines.

In the group beginning on CYBEX NORM, 2 began on the right side, and also in the group beginning on CON-TREX.

Installation

Subjects have been evaluated in a seated position, arms lying against the body, hands holding lateral handles fixed vertically to the shoulders. The trunk has been maintained against the back seat by a 3 points belt–system proposed by each constructor. An additional belt was fixed at the abdominal level in order to minimize trunk compensation on lordosis.

The thigh was attached in order that the closing angle of the trunk suits to 100°.

The knee rotation axis (passing through the center of external condyle) has been adapted to the dynamometer's rotation axis. The length separating dynamometer's rotation axis from where the device leans on the tibia was standardized to $0.30-$m. A controlateral limb stabilizer has been set on the non-tested member in a standard way to 0.30–m.

Angular sector

The movement has been realised with a ROM of 90°. The first adjustment consisted in fixing the anatomical zero and then 90° have been remote. On the two machines, the watchword given to the subjects was to realize movements on the whole angular sector.

Contraction mode and speed

Sportsmen have been evaluated in a concentric mode (the most common practice on the isokinetic market). The execution of the movement went this way:

- 3 experimental repetitions at $180^\circ.\mathrm{s}^{-1}$ followed by 3 repetitions of maximal intensity in flexion and extension
- 2 minutes of recovery
- 3 experimental repetitions at $60^\circ.\mathrm{s}^{-1}$ followed by 3 maximal repetitions

Measure

Peak torque for extensions and flexions have been registered with care of gravity correction.

Warm-up

It was systematized before each test on the machine: 15 minutes on a bike with an intensity of 1 watt per kg of body weight, and was followed by stretching movements of the quadriceps, hamstrings and calf.

On the isokinetic machine, subjects were familiarized with the 2 speeds with 10 under maximal repetitions for each one in the same order as during the test (180 and $60.\mathrm{s}^{-1}$). Each series of 10 repetitions was separated by a period of 20 seconds of recovery.

Operation between 2 tests

The program was as follows for each subject:

1. Bike warm up 15 mins
2. Stretching 7 mins
3. Test 1 on an isokinetic machine
4. Recovery during 30 mins (of which stretching)
5. Bike warm-up 15 mins

6. Stretching 7 mins
7. Test 2 on the other isokinetic machine
8. Subjective questionnaire

Statistics
A student's t-test enabled comparsion between those 2 machines, the peak torque of the extensors (2 sides together), and of the flexors (2 sides together), for each speed. The threshold of significance was $P < 0.01$.

2.3. *Protocol 3*

After they tried the 2 machines, subjects filed a questionnaire which aim was to compare sensations acquired on each one. It concerned:

– The comfort of the machines
– Ergonomics in order to realize a maximum effort
– Muscular sensations
– Safety

3. Results

3.1. *Protocol 1*

When the additional load was of 25 lbs, the average peak torque measured on CYBEX NORM was 61 ± 0.5 Nm and 60 ± 0.3 on CON-TREX MJ. These gaps are not statistically different.

When the additional load was of 50 lbs, the average peak torque measured on CYBEX NORM was 117 ± 1.5 Nm and 115 ± 0.5 Nm on CON-TREX MJ. These gaps are not statistically different.

3.2. *Protocol 2*

At $60°.s^{-1}$ the average of peak of torque of the extensors both sides together is 240.56 ± 53.67 Nm on CYBEX NORM and 242.22 ± 64.51 on CON-TREX MJ (Fig. 1). This difference is not significant.

At $180°.s^{-1}$ the average of peak of torque of the extensors both sides together is 171.56 ± 39.19 Nm on CYBEX NORM and 181.28 ± 42.52 on CON-TREX MJ (Fig. 2). This difference is not significant.

On the hamstrings, at $60°.s^{-1}$ the average is 151.35 ± 34.48 Nm on CYBEX NORM and 155.41 ± 33.28 Nm on CON-TREX MJ (Fig. 3). This difference is not significant.

At $180°.s^{-1}$ the average is 107.65 ± 22.70 Nm on CYBEX NORM and
121.88 ± 26.19 Nm on CON-TREX MJ (Fig. 4). This difference is significant.

3.3. *Protocol 3*

Except during the test, subjects did not find any difference between the two machines as far as the comfort of the chair's back and the foundation was concerned (Table 2).

During maximal effort, subjects preferred CON-TREX MJ ergonomics:

– Best strap up: 77%
– Best stability of the vertical back seat: 77%
– Best stability of the horizontal foundation: 66%

During the effort, 100%of the subjects found the muscular effort more important on CON-TREX MJ, which they all appreciated.

The sensation of safety has been equivalent on both machine for 77% of the subjects.

Some points remained indifferent for those sportsmen:

– Tibial pad
– Controlateral limb stabilizer

Finally, in the eventuality of a new test, 55% of the subjects wished to do it on the CON-TREX MJ, 11% on CYBEX , 33% did not have any preference.

4. Discussion

The main result of this study is the absence of significant difference between the two machines during the measurement of the moment of force producted by a certified additional load. When torques are generated by athletic subjects, both machines give statistically identical results (with, however, an unexplain difference of 10 % for flexors at $180°$/ sec only).

During the manipulation consisting in fixing certfied additional loads at the end of a lever of 0.5 m, the gap between the 2 machines is 1.63% (60-Nm for CON-TREX MJ vs 61 Nm for CYBEX NORM) for a load of 11.375– kg. In this case, we get:

$\mathrm{Mt} = \cos(\alpha)^* \mathrm{d}^* \mathrm{m}^* \mathrm{g}$

Mt: moment of force (Nm)
α: angle formed by the horizontal and the segment supporting the load (in degree)
d: the lever (in m) separating the center of rotation from the mass
m: the mass (in kg)
g: terrestrial gravity (in $m.s^{-2}$)

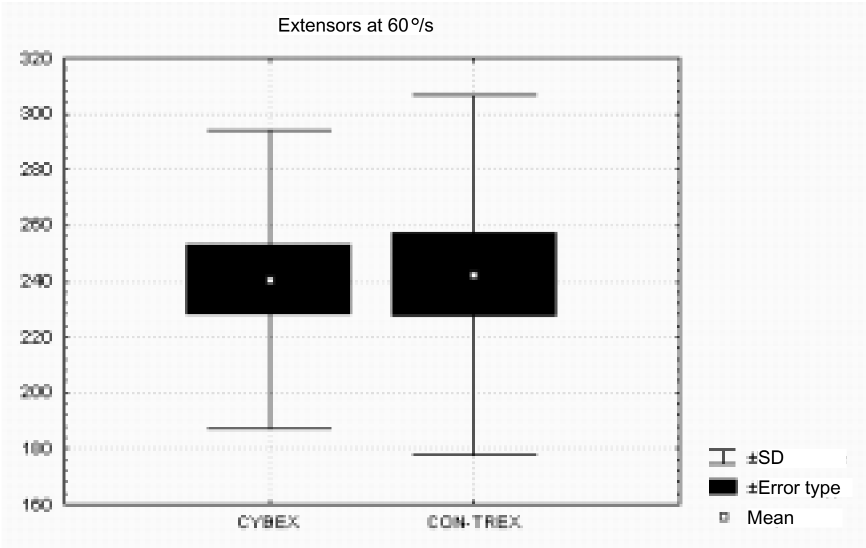

Fig. 1. Peak torque of the leg extensors at 60ª.s-1 on CYBEX NORM and CON-TREX MJ.

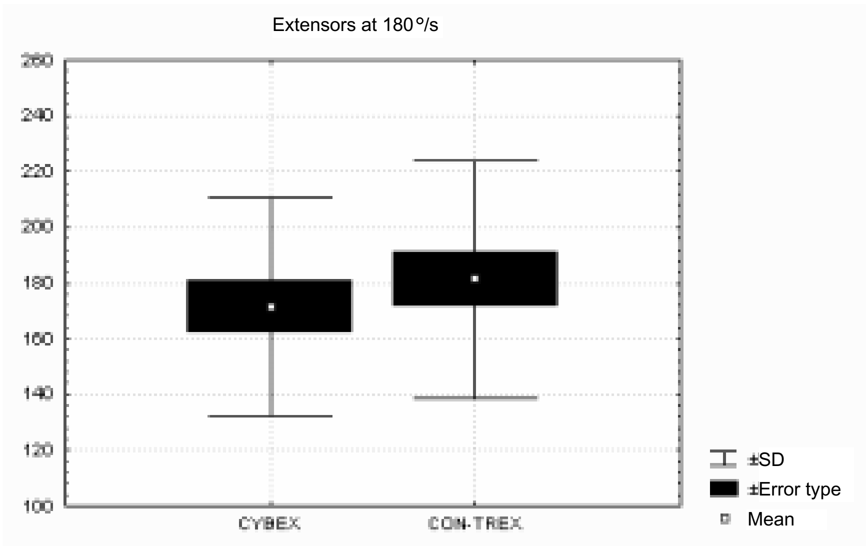

Fig. 2. Peak torque of the leg extensors at $180^{\circ}.s^{-1}$ on CYBEX NORM and CON-TREX MJ. This difference is not significant ($P > 0.01$).

Therefore, the maximal revolving torque is reach when the segment supporting the load is in the horizontal position. In that case, we get:

Mt $= \cos(0)^{*}0.5^{*}11.375^{*}9.81 = 56$ Nm

In the previous study, the measured value is 7.15 % more important on CON-TREX MJ and 8.92% on CYBEX NORM. With 22.75–kg of additional load, the difference between the theoretical measurement (112 Nm) is 2.68% on CON-TREX MJ (115 Nm) and 4.46% on CYBEX NORM(117 Nm).

In those experimental conditions, even more when generated torques are weak, both machines lose some of their precision, but CON-TREX MJ seems to be the more precise.

A possible explanation concerns the degree of precision of the machines during the measurement of the moment of force produced by the machine. The degree of precision is expressed in Nm and would remain constant no matter which moment of force is measured. In consequence, it is when weak torques are measured that the precision of the final absolute and relative result is the more affected.

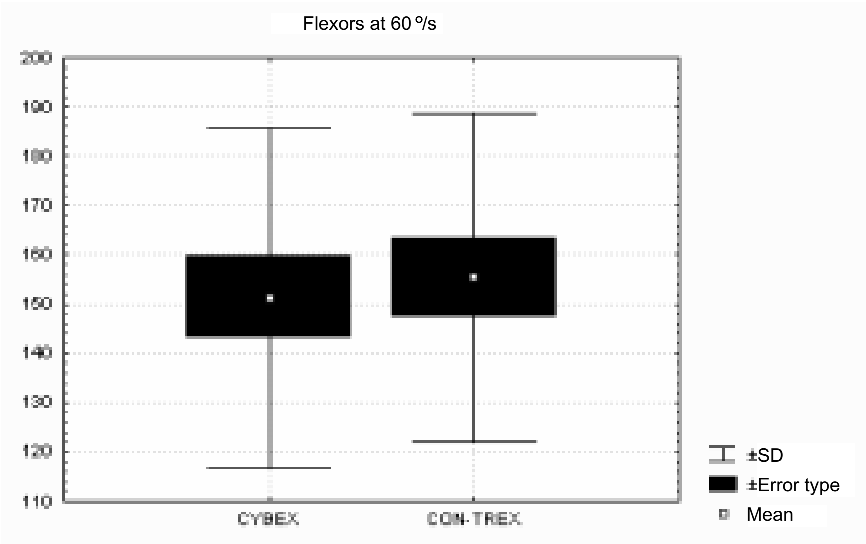

Fig. 3. Peak torque of the leg extensors at 60°.s^{-1} on CYBEX NORM and CON-TREX MJ. This difference is not significant ($P > 0.01$).

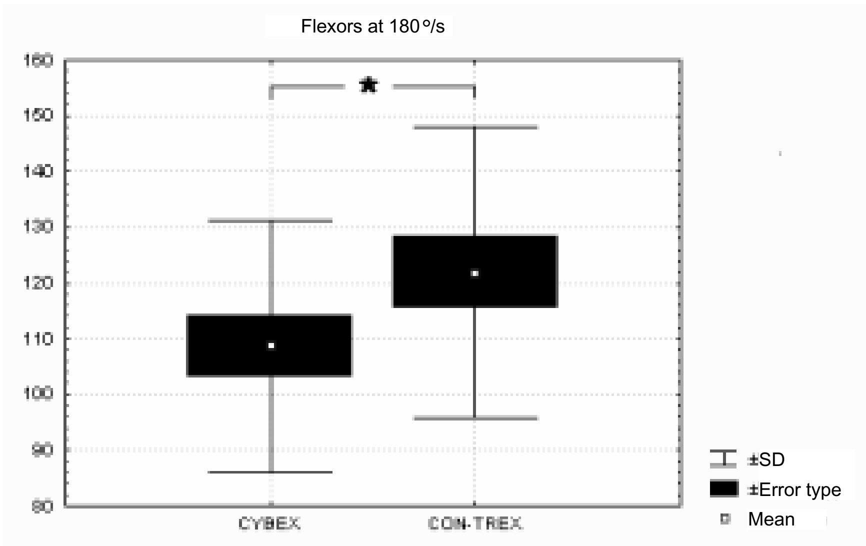

Fig. 4. Peak torque of the leg extensors at 180°.s^{-1} on CYBEX NORM and CON-TREX MJ. This difference is not significant ($P < 0.01$).

Concerning data stemming from high level sportsmen, results have been equivalent to those usually noticed in the literature for sportsmen of the same level [1, 2,9].

Otherwise, those values have been superior to those picked up nearby subjects which sport level is lower [8, 10].

This report seems logical for three reasons :

– The capacity of torque measurement of the 2 dynamometers is equivalent (protocol 1) even more when the absolute values are important.
– The installation of subjects on the 2 machines are identical (angle thigh – trunk (5), ROM , hand fastening mode, size and location of the tibial pad, location of the the controlateral limb stabilizer).
– Both software take account of the gravity of the whole thing formed by the leg and the fastening accessory (12). But it is important to note that the 2 constructors proceed differently:

On CYBEX NORM, the gravity's value (G) for all angular degree (α) is extrapolated from a real mea-

Table 2
Questionnaire results

	Satisfied by CYBEX	Satisfied by CON-TREX MJ	Indifferent
Comfort except during the test			
Vertical back seat	33.30%	55.55%	11.11%
Foundation	44.44%	55.55%	0%
Tibial pad	11.11%	11.11%	77.77%
Hands	11.11%	44.44%	44.44%
Comfort during the test			
Vertical back seat	0.00%	77.77%	22.22%
Foundation	22.22%	66.66	11%
Sanglage	0.00%	77.77%	22.22%
Tibial pad	22.22%	11.11%	66.66%
Controlateral limb stabilizer	22.22%	55.55%	22.22%
Muscular difficulty	0.00%	100.00%	0.00%
Identical safety			
Yes	77.77%		
No	22.22%		
New test			
CYBEX	11.11%		
CON-TREX MJ	55.55%		
Indifferent	33.33%		

surement of $45°$ of flexing, that is to say $G\alpha = \cos(\alpha)^* G45° / \cos(45°)$.

On CON-TREX MJ, gravity is measured for all angles of the angular sector , which made the value more right, specifically to reflect stretching or compression resistance of tissues structures (muscle or other).

However, for the flexor group of the leg, the 2 machines do not give results statistically identical to $1806°.\mathrm{s}^{-1}$.With 121 ± 26 Nm on CON-TREX, results are 10% higher than on CYBEX (108 ± 22). It must be noted that they are the lower absolute values of this comparative test. At this level, the absolute force error may interfere in a non negligible way on the global torque (see Protocol 1). But this trail must be carefully followed since study 1 had taught us that the error on CYBEX increase more the results than the one committed on CON-TREX. Concerning this, we can also ask ourselves on the influence of the acceleration mode on CON-TREX MJ which seems “waken” earlier and maybe more this flexors group of which experience has shown that its contraction in isokinetic mode was sensible to entreaties. Also, others elements must be posed to explained this phenomena. The following paragraph permits to make a inventory of some of the expected explanations.

During the subjective evaluation, all subjects considered that the muscular effort was more important on CON-TREX MJ without any significant effect on the peak of torque. Elements of explanation might concern:

– Strap stabilisator (more efficient on CON-TREX MJ with a three points double belt than on CYBEX NORM with a 5 points belt).
– The seat is more rigid on CON-TREX MJ, which implies a limitation of the lost of energy absorbed by the elasticity of material.
– The settlement of the acceleration phase. Indeed, each machine would proceed in a different way to pass from speed 0 to the pre-established speed and inversely.

In consequence, first, times to reach the constant speed could be different between the 2 machines; second, the isokinetic angular sector could be too.

Then, those 2 parameters can have repercussions on the energy spent (work) and on the registered torque. Indeed, by definition, their calculation can be done only in isokinetic conditions : if the isokinetic angular sector changes between the 2 machines, values of torque and work change as well.

We assume the torque can be affected only during the very first degrees of the ROM corresponding to the acceleration phase. Theoretically, three will not be any difference of torque between the 2 machines (with an equivalent angular position) when they have both reached the constant speed.

Finally, interactions between all those elements could explain why the total energy spending is more important on CON-TREX. But this report does not represent a negative point for the sportsmen because 55% of them would prefer make a new test on this machine instead of 11% on the CYBEX NORM. Further more, the impression of safety felt by subjects is equivalent between the two machines.

5. Conclusion

The purpose of this study has been to show that isokinetic dynamometers like CYBEX NORM or CON-TREX MJ measured identical moment of force during a calibration with the help of certified additional loads. But the precision of the measurement is altered when the moments of force become weak.

Moreover, high level sportsmen tested on those 2 machines in strictly similar conditions (position, angular sector, speed) have produced peak of torque statistically equivalent (out of flexors which at 180°/sec show an unexplain difference of 10%, the CON-TREX machine measuring higher values – cf our discussion). Subjectively, all sportsmen talked about muscular effort more being important on CON-TREX MJ. Elements of explanation would concerned a stronger rigidity of the back seat of the chair and the foundation, a better stabilisation thanks to the straps, a shortening of the acceleration phase before reaching the target speed on the CON-TREX MJ machine.

Regarding those results, it seems obvious that the intrinsic potential of measurement of those 2 machines are identical. But surely more than for ergonomically reasons, a sportsman may feel himself in better conditions on CON-TREX than on CYBEX. It seems that the argument is particularly appealing when the test is realized at high speeds. Further study, using a more important sample, could answer the question concerning the flexors might find an answer.

References

[1] P.M. Aaggard, E.B. Trolle, K. Simonsen, Klausen and J. Bangsbo, High speed knee extension capacity of soccer players after different kinds of strength training, in: *Science and football II*, E. & F.N. Spon, London/New York, Reilly, Clarys, Stribbe, eds, 1993, pp. 92–94.

[2] P. Aaggard, E.B. Simonsen, M. Trolle, J. Bangsbo and K. Klausen, Specificity of training velocity and training load on gains in iskinetic knee joint strength, *Acta. Physiol. Scand.* **156** (1996), 123–129.

[3] T. Bajd and B. Bowman, Testing and modelling of spasticity, *J. Biomed. Eng.* **4**(April,1982), 90–96.

[4] R.W. Bohannon, Variability and reliatbility of the pendulum test for spasticity using a Cybex II isokinetic dynamometer, *J. Am. Phys. Ther. Ass.* **67**(5) (1987), 659–661.

[5] H. Deutsch, Quadriceps kinesiology with varying hip joint flexion and resistance, *Arch Phys Med Rehabil.* **59** (1978), 231–326.

[6] H.J. Hislop and J.J. Perrine, The isokinetic concept of exercise, *Phys Ther.* **47**(2) (Frbuary, 1967), 114–117.

[7] R. T'Jonck and E. Lysens, Witvrouw, The effect of positioning, sex and leg dominance on the plantar and dorsal flexors strength at the ankle, *Isokinetics and Exercise Science.* **6** (1997), 235–241.

[8] B. Öberg, J. Ekstrand, M. Möller and J. Gillquist, Muscle strength and flexibility in different positions of soccer players, *Int J Sports Med.* **5** (1984), 213–216.

[9] B. Öberg, M. Möller, J. Gillquist and J. Ekstrand, Isokinetic torque levels for knee extensors and knee flexors in soccer players, *Int J Sports Med.* **7** (1986), 50–53.

[10] P. Rochecongar, R. Morvan, J. Jan, J. Dassonville and J. Beillot, Isokinetic investigation of knee extensors and knee flexors in young French soccer players, *Int J Sports Med.* **9** (1988), 448–450.

[11] C.F. Roques and V. Bourg, Evaluation isocinétique de la spasticité, *Isocinétisme et Médecine de Rééducation*, Masson. Paris: (1991), 132–137.

[12] D.-A. Winter, R.-P Wells and G-W Orr, Errors in the use of isokinetic dynamometers, *Eur J Appl Physiol.* **46** (1981), 397–408.