DinamometroGC – Elbow and Ankle Dynamometer

The DinamometroGC is a dynamometer designed to measure the torque exerted by the muscles that span the elbow or the ankle joints. It comprises two load cells and can measure force during flexion or extension. The force measured by the load cells can be used to estimate the torque at the elbow or ankle because the position of the load cell, and hence the lever arm, is known and fixed.

Foot/arm positioning

Once the foot or arm has been positioned in the dynamometer (see Fig. 1), the different parts can be moved to the most comfortable position for the subject. The device can be adapted for the elbow or ankle by moving the plate (A), joint angle around the pivot (B), the heel/elbow support (C), and the cushion (D).

Fig. 1. *The DinamometroGC and its parts: A = plate, B = pivot, C = heel/elbow support and D = positioning system for supporting the arm/leg.*

For reliable measurements it is important that the center of rotation for the knee or elbow be aligned with the center of rotation of the dynamometer (see Fig. 2). This can be done by adjusting the plate (A) and the heel/elbow support (C).

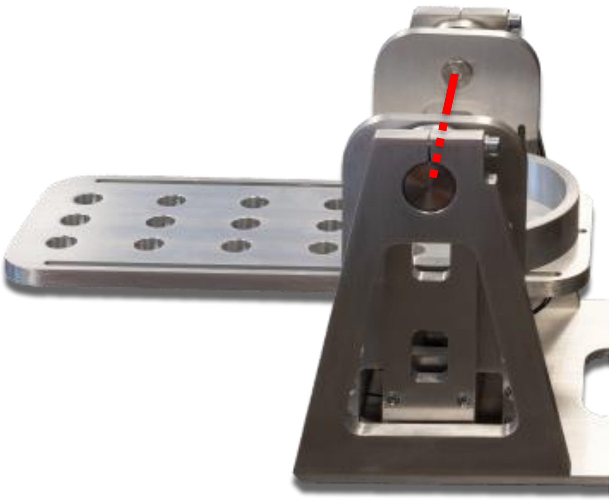


Fig. 2. Alignment between ankle or elbow and dynamometer centers of rotation.

The angle can be varied by adjusting the knobs at the rear part of the dynamometer, using the Allen key that is provided, see Fig. 3.

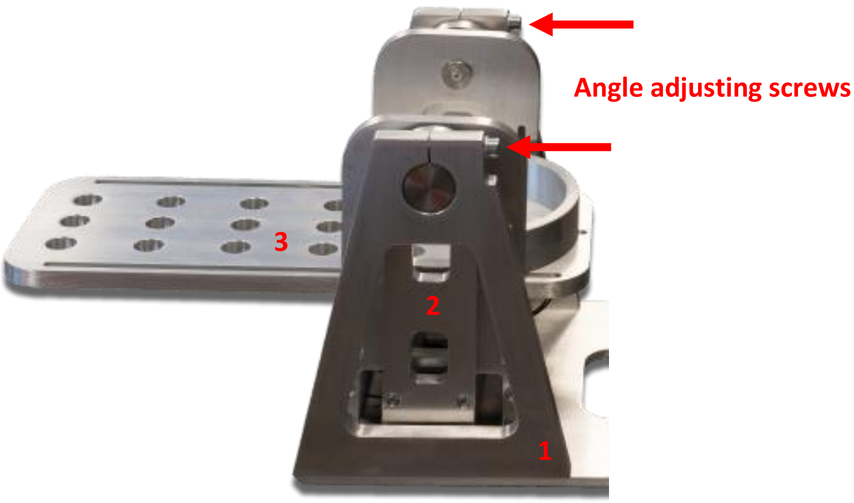


Fig. 3. *Elbow and ankle angle adjustments. The two red arrows show the two screws that can be loosened to change the angle of the knee/elbow by rotating the plate around the pivot. Numbers 1, 2 and 3 indicate the different parts of the dynamometer: 1 = the external frame, 2 = the structure holding the load cells, 3 = the moveable plate.*

The two load cells of the dynamometer are compression load cells. They provide independent measurements of the torque during flexion and extension of the knee/elbow. The DinamometroGC has 3 different parts (refer to figure 3):

1. The frame, which can be fixed to a table, wall, or to the floor.
2. Load Cell structure. This structure holds the load cells. It can rotate around the pivot when the two screws (red arrows in figure 3) are loosened. This structure is fixed to the external frame when the same two screws are tight.
3. Plate structure. This structure is a single block with the plate and must be fixed to the foot/arm of the subject. This portion of the dynamometer can rotate around the pivot and push against one of the two load cells during flexion/extension.

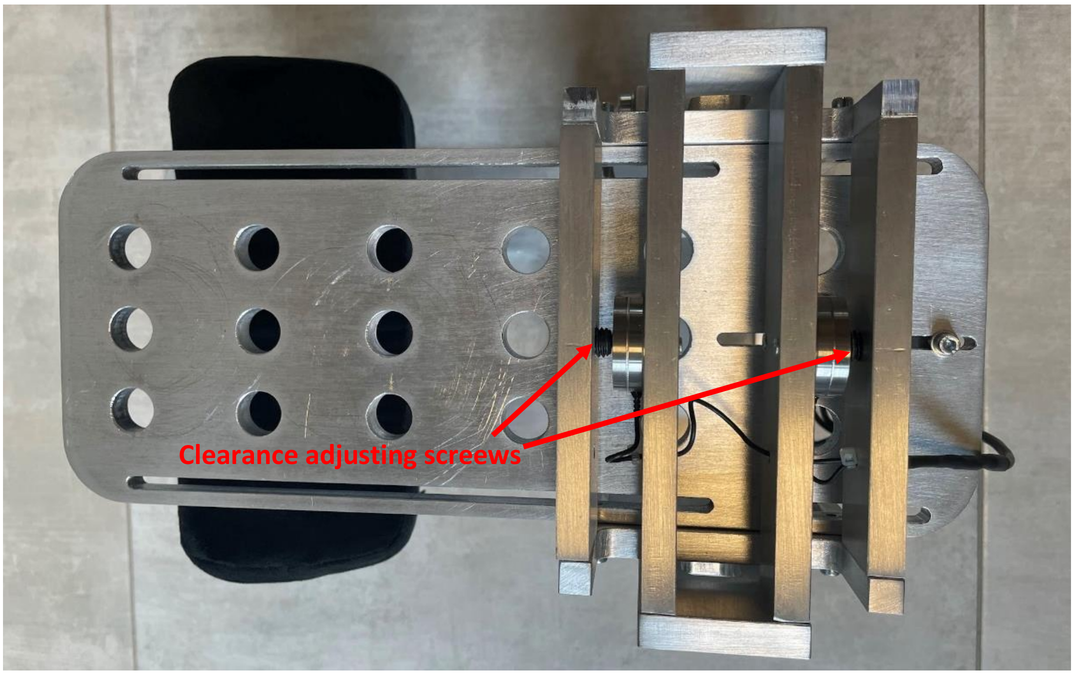


Fig. 4. *Bottom view of the plate with details of the two screws that set the desired clearance between the load cells and the rotating part of the dynamometer.*

Two additional screws allow to calibrate the clearance between the Load cell structure and the plate structure (see figure 4). A minimum clearance is always recommended to avoid hysteresis. The clearance can be adjusted by loosening the two screws so that the plate can rotate over small angle ranges. Then, one of the two screws can be tightened gently to reduce the free movement of the plate structure, but without pushing against the load cells. This adjustment should be verified by looking at the output signal. The signals must not change in the final position.

Use DinamometroGC with forza, forza-b and forza-j devices

forza, forza-b and forza-j are load cell amplifiers designed as accessories for Quattrocento, Sessantaquattro and Sessantaquattro+ device.

All amplifiers have an input connector for the load cells that mates them with the output connector of the DinamometroGC, an option to set the amplification gain among 100, 200, 500 and 1000 V/V, and the ability to compensate the weight of the foot/arm or the offset of the load cell.

Fig. 5. *Forza-b, forza and forza-j load cell amplifier.*

Estimating the Torque from the output of the load cell amplifier

The force sensed by the load cell and amplified by one of the forza devices can be estimated as:

$$Force\ (kg) = \frac{V_{OUTforza}(V) * LCFullScale\ (kg)}{Sensitivity\ (mV/V) * LCSupplyVoltage\ (V) * Gain\ (V/V)} * 1000 \qquad [1]$$

Where:

- $V_{OUTforza}$: is the forza output voltage.
- LCFullScale: is the Load Cell full scale value as indicated in the Load cell labels, the default value is 500 lb (~226.8 kg).
- Sensitivity (output of the load cell): is 20mV/V for a single cell. This value must be divided by two to account for the two load cells of the DinamometroGC that are connected in parallel; use the value 10mV/V
- LCSupplyVoltage: is the voltage generated by the forza to supply the load cell. It is fixed at 5V
- Gain: depends on the setting of the forza, and can be 100, 200, 500 or 1000 V/V
- the 1000 conversion factor is used to convert the output of the load cell in Volts. The sensitivity is provided by default in mV/V

Equation [1] can estimate the force expressed in kg as sensed by one of the DinamometroGC load cells. To translate the force to torque, the force value should be multiplied by the fixed lever arm distance of 140.5 mm (e.g., the distance of the sensing area of the load cells from the pivot).

The torque measured by the dynamometer can be estimated with the following equation:

$$Torque\ (Nm) = Force\ (kg) * 9{,}81\ (N/kg) * LeverArm\ (m) \quad [2]$$

Where:

- Force is the result of equation 1
- 9,81 is the conversion factor between kg and N
- Lever arm is fixed at 0.1405 m

As an example, when a weight of 5 kg is positioned on the plate at 20 cm from the pivot (refer to the section calibration details of this manual), and the gain of forza is set to 100, the output of forza should be about 157 mV, thus:

$$Force\ (kg) = \frac{0.157\ (V) * 226.8\ (kg)}{10\ (mV/V) * 5\ (V) * 100\ (V/V)} * 1000 = 7{,}12\ kg$$

The torque is then:

$$Torque\ (Nm) = 7.12\ (kg) * 9{,}81\ (N/kg) * 0.1405\ (m) = 9.81\ Nm$$

To convert the voltage expressed in V directly into a torque expressed in Nm, it is necessary to provide a scale factor that can be determined from the previous equation. It is fixed for the DinamometroGC but it depends on the gain:

$$ConvFact\ (Nm/V) = 6250/Gain \quad [3]$$

DinamometroGC technical details

In Table 1 are indicated the technical details of the load cells used in the DinamometroGC.

	Parameter	Value
Load Cells	Part number	FC2311-0000-500-L
	Full scale	500 lb or 226,8 kg
	Accuracy	± 1% Full Scale
	Sensitivity of single cells	20 mV/V
	Sensitivity when mounted in parallel	10 mV/V
	Maximum overload	250 % of Full Scale

Tab. 1. *Load cells technical details*

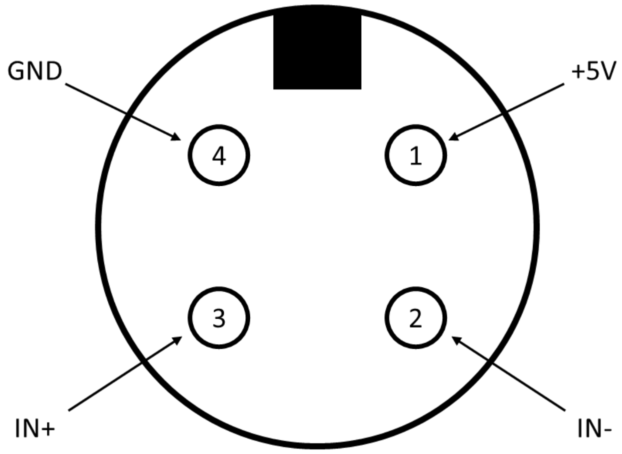
In Table 2 are indicated the technical details of DinamometroGC

	Parameter	Value
DinamometroGC	Type of measurements	Flexion and extension
	Joint	Ankle and elbow
	Load cell Lever Arm	140.5 mm
	Conversion factor Voltage to Torque	6250 divided by the Load Cell Amplifier Gain
	Weight	5.7 kg
	Adjustments	Joint angle Alignment of knee/elbow center of rotation Clearance of free movement Support for leg/arm

Tab. 2. *DinamometroGC Technical details*

Figure 6 shows the pinout and detail about the output connector of the DinamometroGC.

Four-pole male Binder connector
Part Number: 09-9767-70-04



View from solder side

Fig. 6. Load cell connector pinout.

Calibration details

If a calibration of the Dynamometer has to be carried out, few aspects must be taken into account. This chapter highlights the main sources of errors and a guide to perform the calibration of the dynamometer.

Since the two load cells are independent, they should each be calibrated in both the flexion and extension directions. The dynamometer must be positioned, and the joint angle set so that the plate is horizontal, see figure 7.

Fig. 7. *Positioning the DinamometroGC for calibration in flexion and extension. Check that the plate is horizontal and positioned at the end of its range (see red arrows). This ensures that the plate and is perpendicular to the structure.*

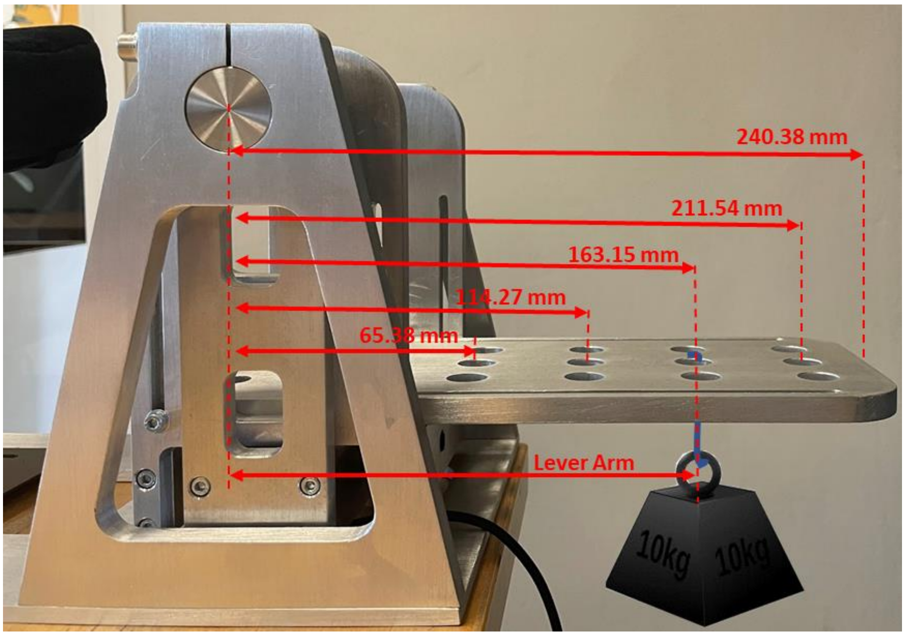


Fig. 8. *Reference distances for lever arm from the center of rotation to the center of the holes in the plate.*

Ideally, the weight should be suspended from one of the holes in the plate.

Using a rope and appending the weight allows to be more precise in the measurement of the lever arm. Distances to the different holes are shown in figure 8 where some quotes are provided.

When evaluating the output value of the load cell amplifier, remove the offset detected before applying the known weight and check that after removing the weight that the offset is still the same. If the offset changes before and after adding and removing the weight, make sure that the clearance adjustment screws are not too tight (refer to figure 4).