⚗ Functional calibration for trunk, lower- and upper-limb fixed inertial sensors

Benedikt Fasel,Jörg Spörri,Josef Kröll,Kamiar Aminian

Abstract

Calibration procedure for functionally aligning inertial sensors fixed to the shanks, thighs, trunk (e.g. sacrum, sternum), head, arms, and forearms / wrists. The movements were originally designed for analyzing skiing movements where the person is wearing ski boots. However, the same protocol can be applyied also barefoot or with regular shoes.

Please refer to the protocol's guidelines for more information how to obtain a sample data set and the matlab code needed to process the functional calibration.

Guidelines

This protocol is an extension of the protocol [Functional calibration for trunk and lower limb fixed inertial sensors](#). Most of the steps are identical to that protocol and the corresponding videos showing the movements from the front and side can be viewed there. This protocol adds one step, arm swing, that allows also to functionally calibrate upper-limb fixed inertial sensors.

- Before each movement, the person should remain motionless for 1-2 seconds to allow better data segmentation.
- Trunk rotation: ski poles are only needed to ensure a better control of the rotation axis. The movement can also be performed with the hands held behind the head.
- Hip ad/abduction: ski poles are only needed for balance. The movement can be performed without ski poles but requires quite good balance control abilities of the person.
- Note: the order of the calibration movements is not important since data processing afterwards is independent of this order. However, it is important to once choose an order and then stick to it forever, to avoid confusion and mistakes.

The code to analyze the data along with an example data set from an alpine skiing athlete is available on Code Ocean, under the DOI 10.24433/CO.23792aee-07c5-4cdc-bfe9-9e85fa1bf5d5 (https://codeocean.com/2017/10/16/inertial-sensor-functional-calibration-and-joint-drift-correction/code).

Before start

Place the inertial sensors on the shanks, thighs, and trunk (e.g. sacrum, sternum), head, arms and forearms / wrists. The exact sensor orientation does not matter, i.e. they don't need to be put in the exact same way for each new experiment. However, the sensors should be placed such as to reduce soft tissue artefacts.

For example, a good location for the shank sensors is the tibial plateau, about 10-15cm below the knee, slightly medially.

The arm sensors should not be placed on or too close to the biceps and the forearm sensor should be placed as close as possible to the wrist so that the axial rotation of the forearm can also be measured accurately.

Protocol

Squats with rolling spine
Step 1.

Slow squats with knee, hip, trunk, head flexion. Arms are parallel to the leg. Perform the flexion movements until the fingers reach the ankles. Perform the movement three times.

Hip ad/abduction
Step 2.

Slow hip ad/abductions of first the right leg. Control balance using the ski poles. Right heel is positioned in-line with left toe. Keep knee straight through the entire movement. Perform the movement of slow hip abduction and adduction three times. Then perform the same with the left leg.

Note: Athletes have the tendency to externally rotate their hip during the hip abduction. The toes should always remain pointing forwards, with no external hip rotation. Train the correct movement a few times prior to perform the entire functional calibration procedure.

Trunk rotations
Step 3.

Slow trunk rotations around the vertical axis with hips fixed. Arms hold a ski pole lying horizontally behind the neck. Head turns with the trunk. Perform the movement three times where the rotation starts by looking to the right.

Arm swing
Step 4.

Slow arm up/down movements in the sagittal plane with straight elbows. The hands hold a pole

horizontally with both thumbs pointing medially. Hands are spaced approximately equal to the shoulder width. Perform the movement three times without lifting the arms too high.

Arm swing frontal view

Arm swing lateral view

Upright standing

Step 5.

Stand upright with knees slightly flexed. Keep equal weight on both feet. Look straight to the front. Stand still for 10 seconds.

Summary

Step 6.

The following video shows all the five calibration movements in one shot.