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Intra and inter test repeatability of accelerometric indicators measured while running

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Abstract

Recently the use of Inertial Measurement Units (IMU's) has been extended to several applications in human activity. In running, several studies show the possibility of using IMU's to measure different indicators of speed and foot strike. However, few studies describe the repeatability of those indicators. In this context, the aim of this study is to analyse the intra and inter test repeatability of several temporal and spectral indicators using an IMU under constant running conditions. Accelerations were measured using three IMU's mounted on the trunk near the lumbar, the right tibia and the dorsal surface of the right shoe above the metatarsals. The subject follows two different protocols to realize the intra test and the inter test repeatability of eight different parameters: root mean square (RMS) values of acceleration, kurtosis, total energy, median frequency, mechanical stiffness, mean stride duration, contact and flying duration. For all parameters the mean, standard deviation and coefficient of variation were computed for each set of test. The coefficient of variation was lower than 5% for both test for all parameters except kurtosis and the median frequency. Parameters with acceptable value at constant conditions of surface and speed can be used as an indicator to compare several conditions, such as the influence of speed, surface or anthropometry of the subjects.

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Keywords: Inertial measurement units, Running, Repeatability, Accelerometric indicators

1. Introduction

The measures of accelerations give important information in biomechanics and particularly in sports for the analysis of movement, shock and vibrations. These measurements have been useful to study forms of locomotion like walking [1], running [2][3], and jumping [4] and to distinguish the intensity levels in those movements [5]. In running, accelerations can represent the shock waves propagating through the human locomotor system. Accelerometric measures are recorded using industrial accelerometers requiring cables and acquisition system. The alteration created by the use of these equipments limit the possibilities to study the movement of an athlete. The use of accelerometric data as a source of information in sports has been expanded recently thanks to the use of Inertial Measurement Units

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(IMU's). The IMU's are presented as an alternative that allow in-the-field performance monitoring without constraining athletes' movements. This device has as advantages its low weight, the possibility to be portable and wearable, that it can be used in field conditions and that it can facilitate extended data collection. Because of these characteristics, the use of this device has been extended to several applications in human activity and to develop commercial wearable systems.

In running, the IMU's have been used to measure the vertical acceleration at the center of mass [6], to identify foot-strike and foot-off instants; to estimate the stance, steps and stride duration in sprint [7], or with a variation of running speeds [1][8][5]; to identify foot-strike pattern [9], to evaluate running asymmetry [10] and to measure stride-by-stride running speed [11]. IMU's placed in the lumbar spine have been used also to isolate every stride [12][13] and to identify the flight duration, contact duration and stride duration. Upon these parameters, the mechanical stiffness can also be calculated [4][14][15].

In order to use a sensor, it has to be validated by a reliability test. In this case, the study of Henriksen et al. in 2004 [1] determine the test-retest reliability of a trunk accelerometric gait analysis in healthy subjects for walking. This reliability is analysed taking as indicators the root mean square value of accelerations, cadences, step and stride lengths for different walking speeds. The results of that study show high interclass correlation and a low measurement error (under 0.01g for mean acceleration).

Thus, several parameters are used in the analysis of running by IMU's, however little is known about the repeatability of these parameters for one subject. The purpose of this study is to test eight parameters extracted from the IMU's accelerometric signal to analyse their inter and intra test repeatability in running while the conditions of speed and surface are constant. Those parameters are computed in the temporal and frequency domains.

This paper is divided in four sections. First, the materials and methods establishing the two protocols and the definition of the parameters. Second, the results of the eight studied parameters are presented in terms of coefficient of variation. Third, a discussion is made over the repeatability of the studied indicators. Finally, a conclusion is made on this study presenting possible future work.

2. Materials and methods

2.1. Subjects

One healthy man was recruited for this test (22 years old, 173cm, 76kg). The subject volunteered to participate in the study, which was approved by the local university ethics review board and was in agreement with the declaration of Helsinki. The volunteer was aware of the purpose of the study and he provided written informed consent. The subject was recreational runner with a training frequency of 2 or 3 times per week and was chosen for his constant practice of running.

2.2. Equipment and data acquisition

The running test was performed on a treadmill (NordiTrack C300). The subject was equipped with three IMU's Hikob Fox (Hikob, Villeurbanne, France) composed of a tri-axial accelerometer. The first one was placed on the foot on the dorsal surface of the right shoe above the metatarsals (Fo). The second was mounted at the centre of mass of the leg, according to the anthropometric data described by Winter [16], on the bony part of the tibia (Ti). The last one was placed on the trunk near the L4-L5 space of the lumbar on the line between the two iliac crests, with one axis of the IMU was aligned with the vertical axis of the body (Lu). The acquisition was made with a sampling frequency of 1344Hz with maximum magnitude of $\pm$24g for the foot and the tibia devices, and $\pm$8g for the lumbar device. The shoe device was mounted on the lace, held in the eyelets of the housings. Tibia and lumbar devices were maintained with a Velcro strip, made for the test. All raw data were logged on a memory card. The three IMU's were synchronized by the use of a radio frequency remote control.

2.3. Protocol

The test was divided into two sequences of ten measures spaced by one day. Before each sequence the subject was asked to warm up by performing two minutes of walking followed with five minutes of running at 12km/h. The two