# Validity and reliability of the WIMU inertial device for the assessment of the vertical jump

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The aim of this study was to test the validity and reliability of the inertial device WIMU (Realtrack Systems SL, SPA) for the assessment of the vertical jump, counter movement jump and squat jump. Fifteen soccer players were evaluated in two identical sessions separated by one week. In each session, participants performed three jumps of each type. The flight time was quantified by the inertial device WIMU and by a force platform (Twin plates, Globus) at the same time. For the analysis of reliability of the flight time of the CMJ and the SJ, the intraclass correlation coefficient (ICC) was used. The calculation of the concurrent validity was performed by using the Pearson correlation coefficient (r). This analysis was complemented with the realization of the Bland-Altman plots. For the analysis of reliability, the coefficient of variation and the standard error of the means were calculated. The analysis presented a high validity and reliability of the device. The results show the inertial device WIMU (Realtrack Systems SL, SPA) as a useful tool for measuring the jump capacity of the athletes, presenting immediate results in real time, on any type of surface and in a simple way since it does not need cables.

1    **ABSTRACT**

3    BACKGROUND: The aim of this study was to test the validity and reliability of the inertial device

4    WIMU™ (Realtrack Systems SL, SPA) for the assessment of different vertical jump modalities.

5    METHODS: Fifteen soccer players were evaluated into two identical sessions separated by one

6    week. In each session, participants performed three jumps of each type. The flight time was

7    quantified by the inertial device WIMU™ and by a force plate (Twin plates, Globus) at the same

8    time. The intraclass correlation coefficient (ICC) was used for the analysis of reliability of the

9    flight time of the Counter Movement Jump and the Squat Jump. For the analysis of reliability, the

10   coefficient of variation and the standard error of the means were calculated.  The calculation of the

11   concurrent validity was performed by using the Pearson correlation coefficient (r). This analysis

12   was complemented with the realization of Bland-Altman plots.

13   RESULTS: The analysis presented a high validity (CMJ: ICC= 0.97, $r$= 0.95; SJ: ICC= 0.96, $r$:

14   0.93) and reliability (CMJ: CV= 3.1; SJ: $r$= 2.5) of the device.

15   CONCLUSIONS: The results showed an almost perfect relation between the inertial device

16   WIMU™ and the contact platform. WIMU™ is an useful tool for measuring the jump capacity of

17   the athletes, presenting results in real time in a simple way since it does not need cables.

19 **INTRODUCTION**

20 One of the most commonly used indicators to assess physical fitness in different in both the general

21 population and high performance sports, and for identifying young talents (1) is the vertical jump.

22 Similarly, it has been used to predict the risk of injury and is associated with muscle power or

23 neuromuscular fatigue (2, 3). In fact, jump performance plays a crucial role in both the

24 predominantly anaerobic and aerobic disciplines, as well as in the mixed disciplines (4, 5). This

25 can be measured by different tools or systems (force plates, video analysis, photoelectric cells,

26 contact mat, video cameras, etc.) (6-8) and more recently with phone apps as MyJump (1).

27 Although they are highly accurate measurement systems, they involve some drawbacks. For

28 example, force plates are difficult to use in field test while the video analysis does not generate

29 immediate results (1). Similarly, video analysis has a major drawback, especially if only one

30 camera is used. If the plane that records the camera moves, the accuracy will be affected (9). There

31 are several means for evaluating vertical jump, therefore it is important to choose the one that

32 bestfits to complete the task, regarding precision, cost, reliability or duration (6). Accelerometers,

33 however, are a highly portable, lightweight, easy to use and accessible tool for almost any coach

34 (7, 10).

35 The vertical jump height is measured as the difference between the position of the center of mass

36 of the individual in the starting position (a standing position) and its position at the maximum

37 height (11). This height can be measured according to the flight time (12). Flight time is the raw

38 data that both devices recorded and is used in several studies (13-15) and reported as the more

39 accurate method to calculate jump height (16). The estimation of jumping performance is done

40 after the event. Also, the jump height is an indirect technique to measure jump height or muscle

41 power and as (8) suggest, the different methods used in the calculation could be led to a systematic

42    error. Not all the measurement systems are equally accurate, in fact it has been reported that, due

43    to the different angles of the knees and ankles at the time of the jump starts, there may be an error

44    of 2.2 cm (15). WIMU$^{TM}$ is an inertial device designed for monitoring the physical activity for

45    athletes of different disciplines.

46    The control of the validity and reliability of the WIMU$^{TM}$ device is necessary for its acceptance as

47    an accurate measurement system for assessing the vertical jump. The validity and reliability refer

48    to the device's ability to measure what it is designed to measure (validity), and to always measure

49    the same event inthe same way (reliability) (17). Therefore, the objective of this study was to

50    evaluate the validity and reliability of the WIMU$^{TM}$ device for assessing SJ and CMJ. It has been

51    hypothesized that the WIMU$^{TM}$ device will display a high validity and reliability for measuring

52    the different vertical jumps used in the study.

53    **MATERIALS & METHODS**

54    *Experimental approach to the problem*

55    The aim of this study was to test the validity and reliability of the device WIMU (Realtrack

56    Systems SL, SPA) to measure the performance in the vertical jump. In order to do that, the tests

57    for measuring the flight time during a slow cycle of stretching and shortening the muscle (CMJ)

58    and the explosive concentric muscle actions (SJ) were conducted by 15 subjects into two identical

59    sessions. Data collections were separated by one week. Jumps were measured with the WIMU$^{TM}$

60    device and the force plate at the same time (Twin Plates, Globus Sport and Health Technologies

61    LLC, ITA), considered as the *gold standard*. The election of flight time as variable of comparison

62    is because is the direct data that provide both systems. Jump height is an indirect measurement of

63    a formula based on flight time. WIMU$^{TM}$ was attached to a belt and fixed on the lower back

64    (Choukuo et al., 2014).

65    *Subjects*

66    The participants in the study were 15 soccer players at early stages (N=15, age = 14.74 ± 0.23

67    years old, height = 164.34 ± 4.04 cm, weight = 65.7 ± 3.35 kg). All the participants belonged to

68    the same soccer team participating at a regional category in Spain. The team trains three sessions

69    of two hours per week, with a total volume of six hours of training. The jumps were performed

70    during the competitive season. All subjects and their parents were informed about the study

71    procedures and their possible risks, giving their consent to participate before testing. The ethics

72    committee of the University approved the study (nº 67/2017).

73    *Procedure.*

74    In both sessions of data acquisition, conditions were the same. During the week of training, the

75    jumps were performed three days after the last game. Before jumping, warming-up was equal in

76    both sessions. A standard warm-up of 15 minutes, consisting of five minutes of continuous

77    running, specific mobility of the lower body for another 5 minutes, active stretching of the lower

78    extremities, and vertical jumps for the last 5 minutes (1, 7). Previously, the subjects had been

79    instructed in performing the different jumps by the same examiner.

80    *Testing procedures:* The subjects performed each CMJ starting from a static standing position,

81    with their arms on their hips and with their knees extended during the flight. Once in position, the

82    subjects were instructed (approximately a 90° angle) as quickly as possible and then jump as high

83    as possible. In SJ, subjects began in the same standing position as in the CMJ, also with their hands

84    on their hips. In this position, they were asked to flex their hips (aprox. 90 °) and maintain this

85    position. After that, the examiner made them wait for three seconds and then cheered them up

86    verbally to jump as high as possible, without making any type of counter movement. In all jumps

87    at takeoff, participants were asked to leave the floor at the same time and always with their knees

88    extended, and land in similarly extended position (7, 18). A total of six jumps were evaluated for

89    each participant, measured with the inertial device WIMU and the contact plate (figure 1).

90    *WIMU$^{TM}$* (Figure 2). For this study, trials have been recorded by the accelerometer at a sampling

91    frequency of 1000 Hz. Accelerometers and gyroscopes integrated in the device were used to

92    correct and calculate the vertical acceleration recordings. All the information is represented in its

93    specific software QÜIKO$^{TM}$, which allows automatic analysis. A mathematic algorithm was

94    developed in order to calculate flight time using total acceleration signal (vector sum of three axis

95    of the accelerometer and information recorded by gyroscopes). Jump height can be calculated with

96    Bosco, Luhtanen (12) equation.

97    *Force Plate.* The force plate "Twin Plates" (Globus Sport and Health Technologies LLC, ITA)

98    (240 x 400 mm) records the data at a frequency of 1000 Hz with an error of less than 1%. It was

99    used at the same time as the inertial device WIMU$^{TM}$. The plate was connected to a laptop

100   computer for the real-time feedback via the software "Ergo system" (Globus Sport and Health

101   Technologies LLC, ITA). Flight time is automatic calculated by the force platform software.

102   *Statistical analysis*

103   A first descriptive analysis with averages and standard deviation was performed to characterize

104   the sample. The intraclass correlation coefficient (ICC) (2.1) was used for the analysis of reliability

105   of the flight time of the CMJ and the SJ. The Coefficient of Variation (CV) was used to analyze

106   the reliability of the instrument. The absolute reliability was determined by calculating the indexes

107   *Standard Error of Measurement* (SEM) [SEM= SD$\sqrt{(1-ICC)}$ where SD is the standard deviation

108   of day one and day two] and the *Minimum Real Change* (SRD) [SRD= 1.96 x $\sqrt{2}$xSEM] (17). Both

109   SEM and the SRD were calculated in absolute terms and in percentage for easier interpretation

110   and comparison with other measuring devices. Similarly, both the SEM and the SRD became

111   percentages to facilitate comparison with other studies. The percentages were calculated according

112   to the following equation: SEM% = (SEM/mean flight time of the two repetitions)·100; and

113   SRD%=(SRD/mean flight time of the two repetitions)·100. All the reliability tests were performed

114   for the force plate and the inertial device. Similarly, the SEM and the SRD are indicators that

115   express the absolute reliability of the device, shown at the same measurement unit of the

116   instrument. Besides, the SEM results are highly independent from the population under study, not

117   as the ICC (17). To extrapolate the results of the study, it has been chosen to express these indexes

118   in absolute terms, thus being able to compare the results with those of other instruments more

119   easily (19).

120   The calculation of the concurrent validity was performed by using the Pearson correlation

121   coefficient (r). This analysis was complemented with the realization of the Bland-Altman plots.

122   This representation indicates the degree of agreement between both instruments, not only the

123   degree of relation (20).

124   The level of significance was established at $P < 0.05$. All of the analyses were performed by using

125   the statistical package SPSS 21.0 for Windows (IBM Co., USA), except for the Bland-Altman

126   plots, which were performed by using the software Graphpad Prism (Graphpad, Inc., USA).

127   **RESULTS**

128     The descriptive analysis showed that the flight time registered by the inertial device WIMU™was

129     almost identical than the one registered by the plate (Table 1), but there were no significant

130     differences between both devices. The average flight time in the CMJ was: force plate = 437.62

131     ms; WIMU™ device = 437.31 ms. For the SJ, flight time was: force plate = 416.72 ms; WIMU™

132     device = 416.11 ms. The results showed an almost perfect relation between the inertial device

133     WIMU™ and the contact platform, both in the CMJ (ICC (2.1) = 0.97, 95% CI: 0.96–0.98, P <

134     0.001) as in the SJ (ICC (2.1) = 0.96, 95% CI: 0.94–0.97, P < 0.001). The reliability analysis

135     showed a SEM% of 2.2% for the CMJ and of 1.4% for the SJ. The SRD% is 6.2% for the CMJ

136     and 3.9% for the SJ. The CVs were very low for both periods of flight time of jump (CMJ: 3.1%;

137     SJ: 2.5%) (Table 1). In addition, the Pearson correlation coefficient is almost perfect in both cases

138     (r >.9) (Table 1 and Figure 3 and 4).

139     Bland-Altman plots show an average systematic trend of 1.31 (0.29%) milliseconds between the

140     force plate and the inertial device in the CMJ; and an average systematic trend of 0.61 (0.13%) in

141     the SJ. The trend is the average difference between the two measures. As these values are positive,

142     the force plate gets higher values than the inertial device (Figures 5 and 6).

143     **DISCUSSION**

144     The objective of the present study was to evaluate the validity and reliability of the WIMU™

145     device for the assessment of the flight time of squat jump and countermovement jump. The results

146     show the high concurrent validity and reliability that the WIMU™ device presents compared with

147     a force plate. The WIMU™ device has proven to be a useful instrument. The results from this

148     study conclude that WIMU™ provides similar flight times in squat jump and countermovement

149     jump to the criterion method.

150    In previous studies, correlation coefficient has been the main method to assess validity and

151    reliability. It has been suggested that other methods, as Bland-Altman plots, provide more relevant

152    information about agreement between two measures (20). For example, it has been probed that

153    Myotest and Optojump have a high correlation according to ICCs (0.98), but with a systematic

154    bias of around 7 cm in vertical jump (7). In fact, a constant error will not be detected on the

155    correlation analysis and, therefore, it cannot be concluded that devices are accurate (9). The data

156    presented in the Bland-Altman plots show that most of the jumps are close to the media of the

157    differences between instruments in both jump modalities, showing a high level of agreement (20)

158    and a high correlation between them. The ICC presents a great precision of measurements (>0.93).

159    Similarly, by analyzing the reliability of the devices, excellent CVs (< 10%) can be appreciated

160    (11, 19). The SEM% shows very low percentages of absolute error (21).

161    Several studies have examined the validity of different methods of analysis of the vertical jump in

162    comparison to force plates. Previous studies have misreported the vertical jump performance,

163    found discrepancies between devices compared with force plates of around 10 cm measuring flight

164    time (16, 22) or  measuring jump height, from recorded flight time, in contact mats (16, 23). It has

165    also been reported that mastery of the jumping technique may affect the jump performance (23).

166    On the other hand, contact mats measure flight time according to the moment when the subject

167    leaves the ground, and miss some data of the initial rise of the centre of mass before the take-off

168    (23). Also, the differences could be due to the different ascending and descending phases and

169    landing (16). In fact, some studies report as limitation the lack of gyroscope that can detect the

170    inclination of the body in take-off and landing (7, 25).

171    Studies have shown lower values for the validity (ICCs scores), of their devices to those found

172    with the WIMU™. Choukou, Laffaye (11) studies the validity of the Myotest in comparison to a

173 force plate, finding ICC values between 0.86-0.96. Casartelli, Müller (7), by studying the same

174 device, finds similar results. The analysis of reliability shows very low CVs, better than those

175 found when the reliability of mobile applications was developed (26), photoelectric cells (27), or

176 other inertial devices such as accelerometers (7, 11). When the results are compared to the ones

177 obtained with high-speed cameras, the results are practically the same (25). Force plates are

178 considered the most accurate tools for measuring the vertical jump, since they allow identifying

179 the moment of take-off with great precision (25, 27, 28). This device, force platform, is enable to

180 measure, in eccentric and concentric phase of the movement, the force and power production (23),

181 allowing more detailed analysis of subjects´ training. WIMU™ allows providing a similar analysis

182 of force plates (as results concluded) and, contrary to force plates, WIMU™ still records data of

183 more variables during flight time (such as G force in take-off and landing or inclination, among

184 others), which makes the  analysis more detailed. These results demonstrate the ability of the

185 WIMU™ system to play the measurements that a force plate makes, having the advantage of being

186 lightweight and portable. These measurements are valid for both the CMJ and the SJ. Due to its

187 properties of size and weight, this device can be easily placed in any segment of the body to

188 measure the vertical jump (center of mass, hips, back, lower body, etc.). The data collection is

189 done with a single computer wirelessly connected to the device, so a great time preparing for the

190 test is not needed. In addition, subjects do not have to be connected by any cable or have to take

191 off and land in a delimited area. Moreover, thanks to the specific software, the device provides

192 immediate feedback.

193 **CONCLUSIONS**

194 Because of the ability of this device to collect data on different types of jump and the relevant

195 information from these, WIMU™ is a valuable tool for controlling the training and competition.

196 Throughout control of the jumps, changes produced by a particular training program can be

197 detected, being able to redirect or modify it according to the results (7). It can also be used to

198 determine the fatigue accumulated during the same work, adapting the breaks between sets for a

199 full recovery (10, 29). The WIMU™ device does not need cables, so it greatly facilitates its

200 placement in the subject's body as well as the freedom of movement.

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279    **Figure 1.** A graphic example of flight time data of WIMU and force Plate.

280    **Figure 2.** WIMU inertial device.

281    **Figure 3.** Concurrent validity between force plate and WIMU: CMJ.

282     **Figure 4.** Concurrent validity between force plate and WIMU: SJ.

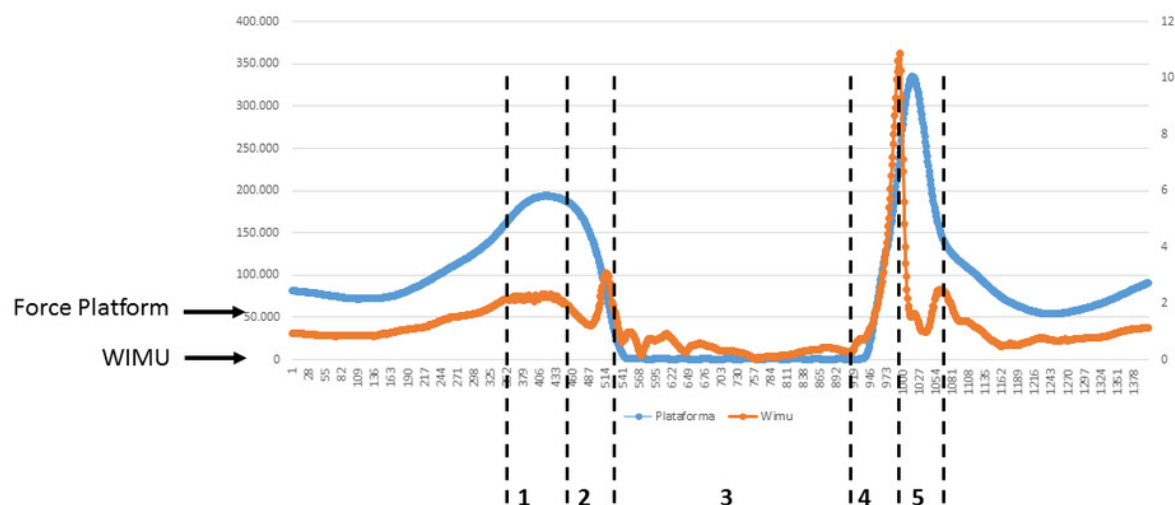
283     **Figure 5.** Bland-Altman plots for force plate and WIMU in SJ. The central line represents the absolute average difference between
284     instruments. Short-dashed lines represent the upper and lower 95% limits of agreement.

285     **Figure 6.** Bland-Altman plots for force plate and WIMU in CMJ. The central line represents the absolute average difference
286     between instruments. Short-dashed lines represent the upper and lower 95% limits of agreement.

287

# Figure 1

A graphic example of flight time data of WIMU and force plate.

Squat jump recorded by WIMU and Force platform.

(1) Knees flexion (concentric); (2) Takeoff; (3) Flight time; (4) Touch-down; (5) Knees flexion (eccentric).
The orange line represent Wimu inertial device measured in gs (right axis). Blue line represent force platform
measured in Ns(Left axis)

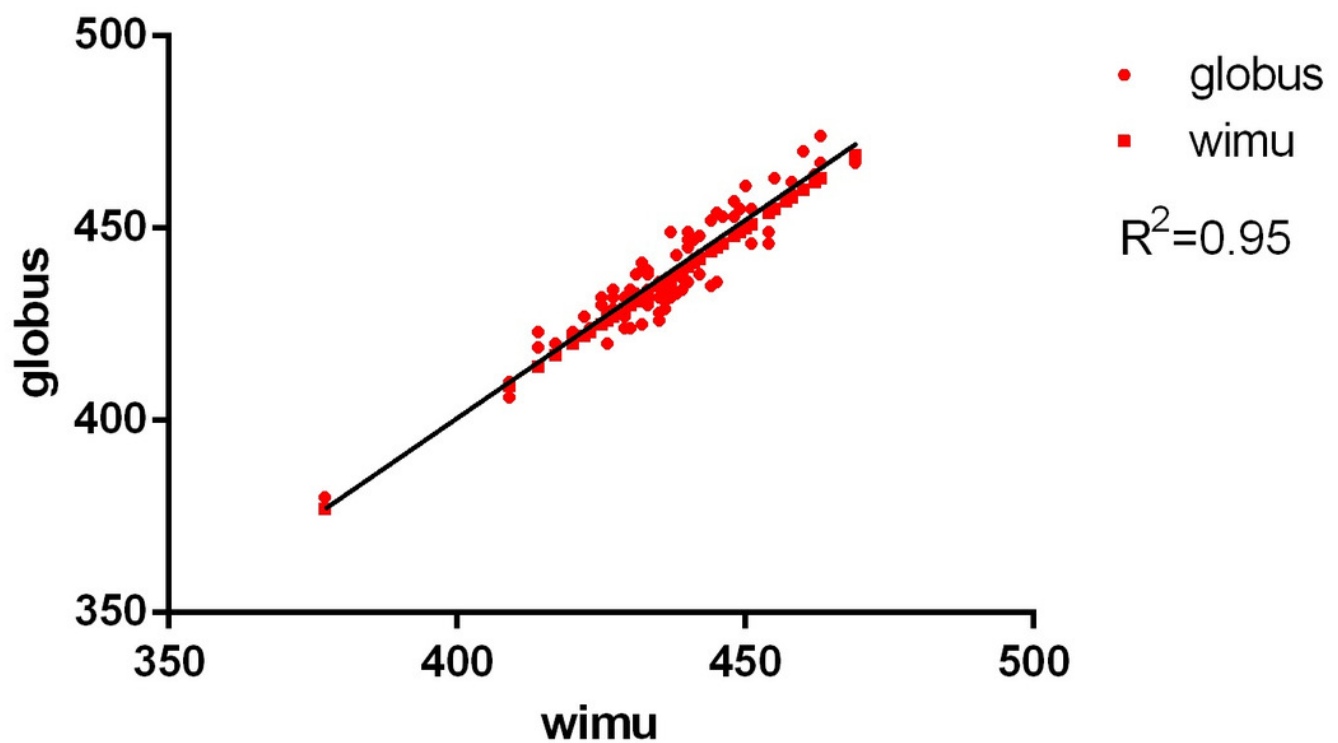
# Figure 2

WIMU inertial device

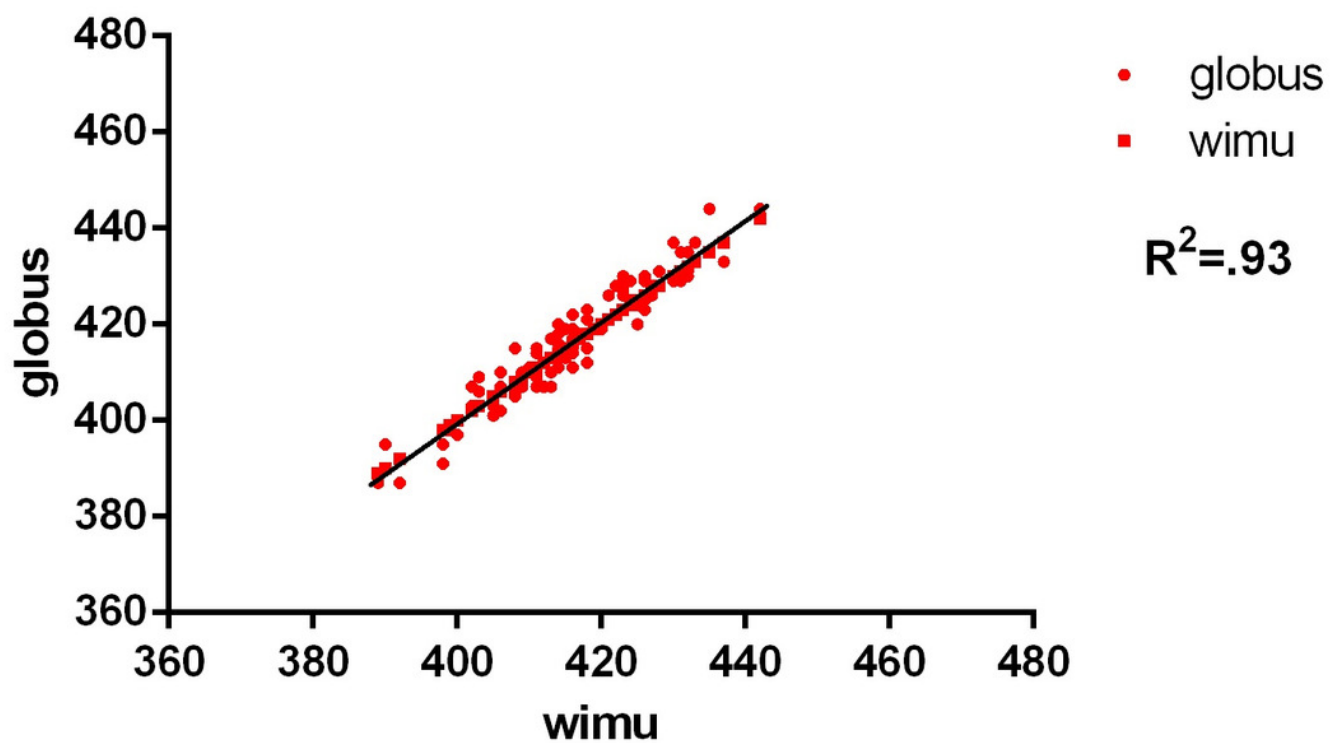
Photo credit: Sergio Ibáñez and Javier García.

# Figure 3

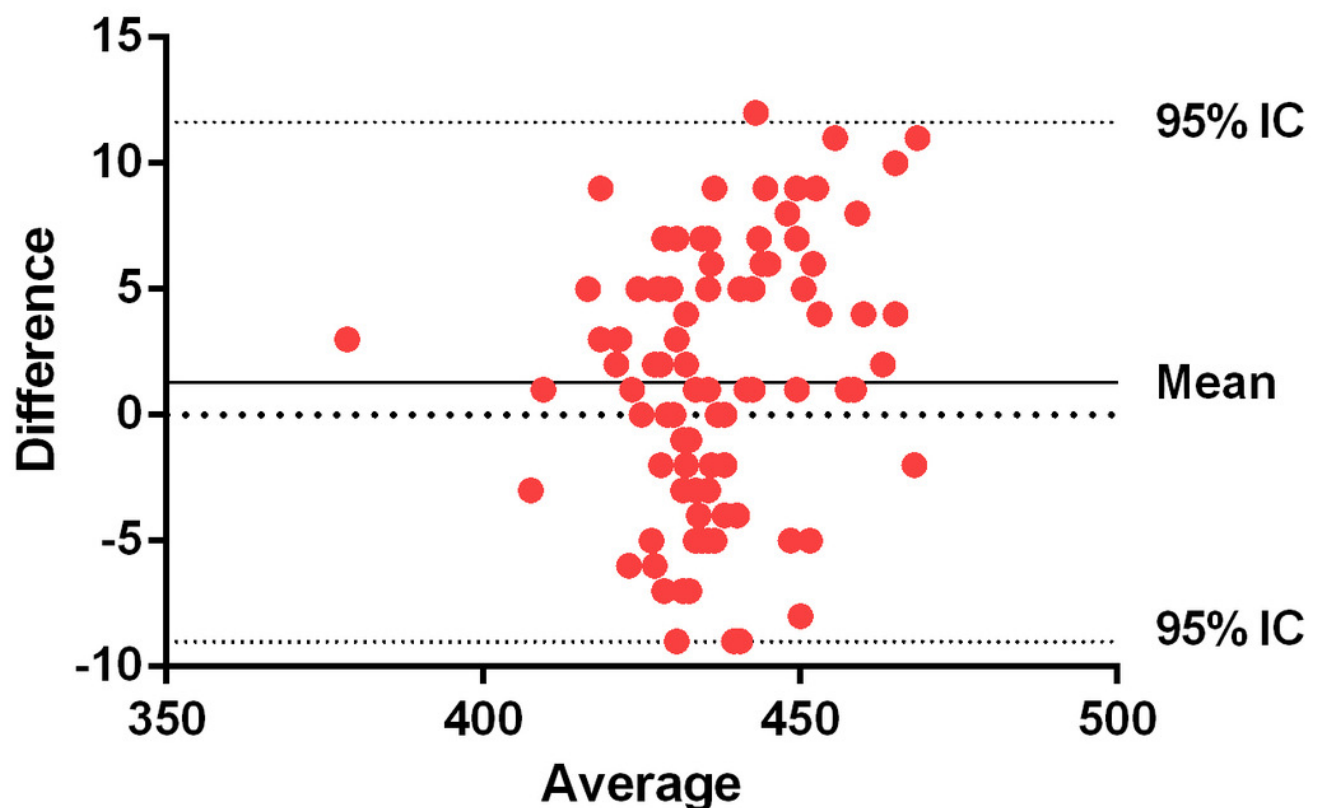
Concurrent validity between force plate and WIMU: CMJ.

Correlation of CMJ (ms).

# Figure 4

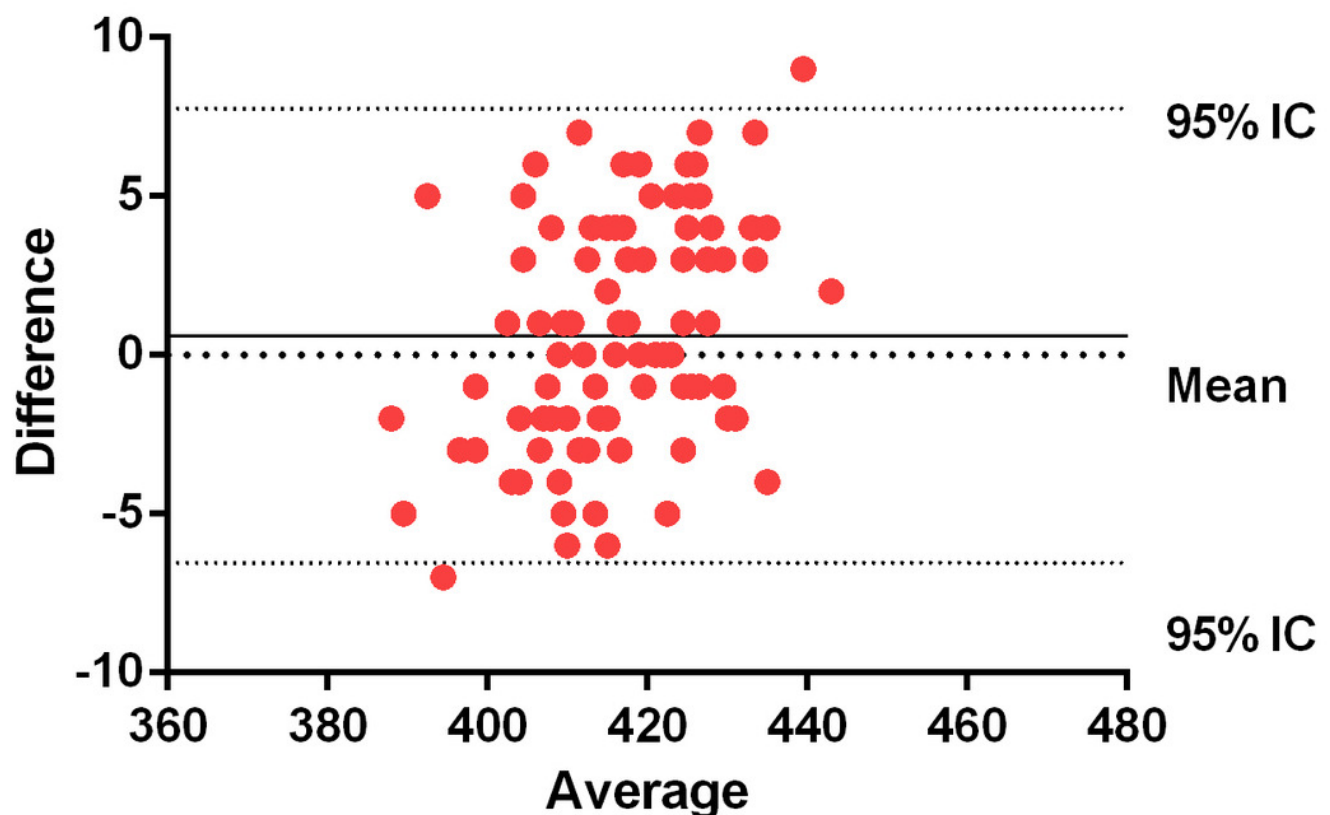
Concurrent validity between force plate and WIMU: SJ.

Correlation of SJ (ms).

# Figure 5

Bland-Altman plots for force plate and WIMU in SJ.

The central line represents the absolute average difference between instruments. Short-dashed lines represent the upper and lower 95% limits of agreement. Counter Movement Jump (Flight time) (ms).

# Figure 6

Bland-Altman plots for force plate and WIMU in CMJ.

The central line represents the absolute average difference between instruments. Short-dashed lines represent the upper and lower 95% limits of agreement. Squat Jump (Flight time) (ms).

Descriptive Statistics (Flight time in ms and jumping performance in cm), intraclass correlation coefficients, reliability of the inertial device and flight time correlation of the CMJ and the SJ.

| Table 1. Descriptive Statistics(Flight time in ms and jumping performance in cms), intraclass correlation coefficients, reliability of the inertial device and flight time correlation of the CMJ and the SJ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | WIMU | GLOBUS | ICC | IC 95% | r | SEM | SEM% | SRD | SRD% | CV% |
| CMJ | Time | 436.31±13.70 | 437.62±14.91 | 0.97 | 0.96–0.98 | 0.95 | 9.69 | 2.2 | 26.85 | 6.2 | 3.1 |
| | Performance | 23.34±0.02 | 23.48±0.02 | | | | | | | | |
| SJ | Time | 416.11±10.70 | 416.72±12.50 | 0.96 | 0.94–0.97 | 0.93 | 5.60 | 1.4 | 16.35 | 3.9 | 2.5 |
| | Performance | 21.23±0.01 | 21.29±0.02 | | | | | | | | |