# Comparison between Gyko inertial sensor and Chronojump contact mat for the assessment of Squat Jump, Countermovement Jump and Abalakov Jump in amateur male volleyball players, amateur male rugby players and in high school students

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***Abstract*** - The aim of this study is to compare vertical jump data obtained by two different measurement systems (Gyko accelerometer and Contact Mat) in order to assess the validity of the Gyko accelerometer as an alternative to the contact mat method. Ninety-six subjects (15.9 ± 1.4 years) performed a single Squat Jump (SJ), Countermovement Jump (CMJ) and Abalakov Jump (ABK). Jump height was simultaneously quantified with the Gyko system and the Chronojump Contact Mat (Criterion Device). Compared to the Contact Mat data, Gyko data determined no significant systematic bias for mean SJ (0.24 cm, $p < 0.05$, $d = 0.04$), CMJ (-0.01 cm, $p < 0.05$, $d = 0.001$) and ABK (0.001 cm, $p < 0.05$, $d = 0.0002$) height. Random bias was ± 5.69 cm for SJ, ± 4.59 cm for CMJ and ± 6.84 cm for ABK height. Pearson R-value demonstrated good to excellent correlation (SJ = 0.89; CMJ = 0.94; ABK = 0.92) between the two devices and Student's T-test demonstrated no statistical difference between the data obtained (SJ = 0.42; CMJ = 0.97; ABK = 0.98) with the two different methods.
Regression equations were provided to estimate the true jump height from Gyko derived data. Our findings indicate that Gyko system can be used interchangeably with Chronojump Contact Mat. It is suggested that practitioners apply the given correction equations for a more precise jump height estimation. The authors would suggest performing multiple set for assessing the endomorph subjects when assessing Squat Jump (SJ) because of increased errors due to soft-tissue movement artefact. Increasing the number of sets and then taking the mean value would decrease the random bias.

***Keywords*** - *Accelerometer, Bosco, Vertical Jump, Explosive Power*

## I. INTRODUCTION

Assessing performance is a practice widely spread among S&C coaches thanks to the fact that it helps them in quantifying the improvements after a meso or a macro cycle, determine the performance level of the team at the beginning of the pre-season, monitor an injured athlete, etc. In the testing battery of many sports (e.g. rugby, volley, tennis, basketball), performance measurements using the vertical jump represents one of the most used assessment [10, 12, 13]. This test is often used for assessing the changes in performance over time and for talent identification [10, 14].

There are several possible methods of assessing vertical jump height and thus explosive power: the gold standard is the force platform [1, 15], nevertheless other cheaper and more transportable instruments such as contact mat (e.g. Chronojump (Chronojump-BoscoSystem®, Barcelona, Spain), etc.), infra-red mat and inertial sensor (e.g. Gyko (Microgate S.r.l, Bolzano, Italy), Optojump Next (Microgate S.r.l, Bolzano, Italy), Vert (VERT®, Fort Lauderdale, Florida), BeastSensor (Beast Technologies S.r.l., Brescia, Italy), etc.) are often used.

Contact mat are the cheapest valid (Pearson R-value compared to an oscilloscope: 1.0) [11] and reliable (ICC 0,998 for the Squat Jump and 0,997 for the Countermovement Jump compared to the Force Platform) [1] tool to assess vertical jump. Considering the previously reported ICC contact mats can be considered criterion-devices. Inertial sensors in addition can be used on uneven ground, with wet or windy weather conditions, they do not require precise alignment of the infra-red emitter and receiver (unlike infra-red mats) and can be therefore more specific to the sport environment [2]. Gyko despite other IMU (e.g. Sensorize, Myotest and Keymove) is not validated [2].

Considering the fact that a previous study [2] found a poor intraclass correlation between the Gyko and Force Platform (ICC 0,81 for the Squat Jump and 0,87 for the Countermovement Jump) and the fact that many studies are made with contact mat, this study aims to investigate the ICC between Gyko data and Chronojump contact mat data to provide Gyko owners with a regression equation useful for the data-conversion from the two different systems.

Finally, considering that the only previous study investigating Gyko validity was performed on a really small population of 19 female youth soccer players [2], this study would like to re-examine Gyko validity on a wider population (96 male and female from various sports provenience). Considering the fact that also Abalakov jump (CMJ with the use of upper limbs) is a useful test to assess jump ability, this test will be used in the study.

With reference to findings from previous studies [3-5] investigating concurrent validity of inertial sensors for the assessment of jump height, we hypothesized that the Gyko system is a valid tool for estimating vertical jump height obtained during the performance of SJ, CMJ and ABK in trained individuals.

Gyko Inertial sensor, compared to other criterion devices (Optojump, Vicon system with markers and force platform), is cheaper, easier to administer and transport and more ecologically applicable (i.e. It can be used in mud, grass, rain, wood, concrete for the assessment of the athlete in different surfaces). Therefore, because of those benefits, it would be useful to be validated.

## II. METHODS

Ethical permission was given by the Scientific committee (Institutional Review Board) of the Italian Weightlifting Federation (Prot. 1058/gr) on the date of 3rd May 2018 and all experiments were conducted according to the latest version of the declaration of Helsinki.

### 2.1 Experimental Approach to the Problem

A single group study design was used to examine concurrent validity of the Gyko inertial sensor system for the assessment of SJ, CMJ and ABK height. Vertical jump height was simultaneously assessed using the Gyko Inertial sensor attached via a Velcro belt to the waist (Fig.1) and the Chronojump contact mat was placed on the ground where the subjects were tested. For safety the A2 contact mat platform has been attached to the ground with american tape (Fig.1).

*Figure 1 – Gyko hip-placement and Mat secured to the ground with some american tape.*

### 2.2 Subjects

Fifteen female with different sport background (artistic gymnastics n= 2, volleyball n= 6, fencing n= 1, athletics n= 1, swimming n= 3, boxe n= 1, calisthenics n= 1) with a mean (±SD) age of 15,4 ± 2,23 years, body height of 173 ± 21,2 cm (using Portable Stadiometer SECA 213, Range: 0.20-2.05m, Sensitivity: 0.001 m), body mass of 65,59 ± 12,68 kg (using Garmin Index Smart Scale, Capacity: 181.4 kg, Sensitivity: 0. 1 kg) and training experience of 10,62 ± 2,51 years and eighty-one males with different sport background (volleyball n= 15, rugby n= 22, football n= 22, handball n= 2, basketball n= 3, water polo n= 2, breakdance n= 3, tennis n= 1, swimming = 2, ski n = 1, judo n= 2, weightlifting n= 1, calisthenics n= 3, judo n= 1, wrestling n= 1) with a mean (±SD) age of 15,98 ± 1,32 years, body height of 178 ± 8,9 cm, body mass of 70,39 ± 12,34 kg and training experience of 10,58 ± 2,23 years volunteered to participate in this study. Subjects were excluded if they had any history of musculoskeletal, neurological, or orthopaedic disorder in the lower extremities within the preceding six months that might have affected their ability to execute the experimental protocol. Before the start of the study, written informed consent was obtained from the participants and their legal representatives.

### 2.3 Equipment

#### Gyko System

Gyko inertial sensor system (dimensions: 50x70x20mm; mass: 35g; Microgate S.r.l, Bolzano, Italy) contains three-axis accelerometer, gyroscope, and magnetometer, which allows recordings (full scale range: 8 g) at a sampling frequency of 500 Hz. During assessment, accelerometer and gyroscope signals are transferred via Bluetooth to a personal computer (HP Pavilion DV6, 15.6-inch, i7-3610QM 3rd gen., 2.3GHz, 4GB RAM) and stored using the proprietary software (Gyko Re-Power Software). The software automatically calculated vertical jump height from the obtained flight time using the following formula: jump height = 1/8 * g * t2 where g is the acceleration due to gravity and t is the flight time [10, 11].

#### ChronoJump Contact Mat

Chronojump contact mat (Chronojump-BoscoSystem®, Barcelona, Spain) was used as a criterion device, it consists [6] on two sheets of fiberglass, one above the other, separated by double-sided tape. The fiberglass plates were laminated with copper on each surface to ensure their conductivity. The double-sided tape was placed along the four sides of the platform in order to keep them close together but ensuring separation of the two until the resistance of the platform is overcome by the weight of the subject. The tape was placed intermittently so that the platform could ‘breathe’ and so avoid the production of a ‘vacuum’ as the individual takes off; this would cause the plates to stay in contact too long and falsely shorten the measurement of the jump. In the case of the A2 platform, a small piece of tape was placed in the centre in order to avoid it becoming deformed due to its large size. The connection cable with the microcontroller was soldered to the lower plate and the connection was protected so that there was no contact with the upper plate. To avoid injuries, improve adherence and improve the appearance of the apparatus, the plates were covered with vinyl, taking good care to allow the platform to breathe at the sides. Contact mat was secured to the ground as can be seen on Fig.1.

According to De Blas et al. [6] Chronojump contact mat has an average activation sensitivity of 65N. Nevertheless, using Eleiko calibrated disk, the author determined that a load of 3.0 kg (i.e. 29,43 N) is the minimum load required to activate the contact. The sampling rate of the microcontroller (Chronopic - Fig.2) is 1000Hz and the threshold (minimum contact time) that can be set from the Chronojump program goes to 10 to 100 ms and on the program manual it is stated that a 50ms threshold (approximately 3cm jump height) is enough to avoid electronic noise interferences.

Contact mat demonstrated excellent reliability (ICC 0,998 for the Squat Jump and 0,997 for the Countermovement Jump) compared to the Force Platform [1], furthermore it is now considered a valid and can be used interchangeably with the gold standard force platform [1, 11]. In this study Contact mat will be used as a criterion device.

Mean of absolute error in the microcontroller was 0.1% in contact time and 0,18% in flight time (taking into account only the most common frequencies, i.e. 150 to 700ms) [6].

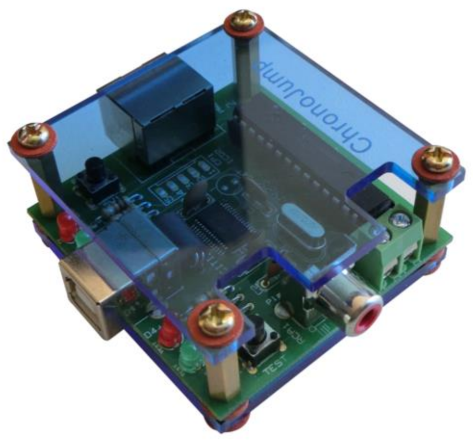


*Figure 2 – Chronopic: Chronojump's Micro controller*

2.4 Procedures

Two weeks prior to the testing day, participants were familiarized with the procedures and trained in the three jumps (SJ, CMJ and ABK). Participants trained in jumping protocol for the following two weeks.

Prior to testing, all participants practiced a warm-up consisting of submaximal plyometric exercises, mobility and core stability. Then participants were, once again, familiarized with the test procedures. Finally, they performed one jump trial for each jump type with a one minute rest between jumps.

During each jump type, maximal vertical jump height was simultaneously assessed using the inertial sensor (Gyko) and the contact mat (Chronojump). Quality of the jump technique was controlled through visual on-site inspection of the experimenter, bad execution of jump resulted in 1' recovery and repetition of the trial.

For the SJ, participants were instructed to start the trial at approximately 90° knee angle with hands placed on hips. On the start signal, participants had to perform a maximal vertical jump without prior downward movement (Concentric only). For the CMJ, participants started from an upright standing position. Subjects were instructed to begin the jump with a downward movement, which was immediately followed by a concentric upward movement, resulting in a maximal vertical jump.

For the ABK, participants started from an upright standing position. Subjects were instructed to begin the jump with a downward movement, which was immediately followed by a concentric upward movement, resulting in a maximal vertical jump; despite CMJ in ABK participants were instructed to swing the arms for helping them reach the highest jump height.

During SJ and CMJ, hands were held on the hips with elbows pointing outside and the depth of the downward movement was freely chosen to allow a natural movement. All jumps were performed barefoot (socks only for hygienic reasons).

Examples of jump data output graph (velocity vs time) recorded by the Gyko inertial sensor system are provided in Fig. 3 a, b and c for the SJ, the CMJ and the ABK respectively.

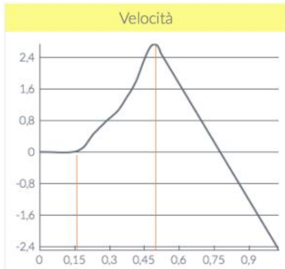


*Figure 3a – Squat Jump (SJ). Concentric and flight phase are divided by the red line.*

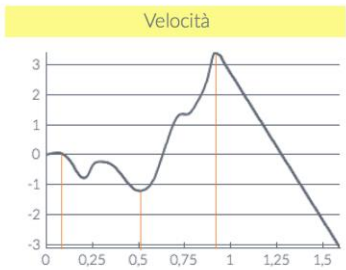


*Figure 3b – Countermovement Jump (CMJ). Eccentric, concentric and flight phase are divided by the red line.*

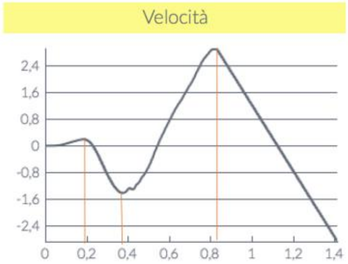


*Figure 3c – Abalakov Jump (ABK). Eccentric, concentric and flight phase are divided by the red line.*

2.5 Set-up

Contact mat was attached to the ground with an american tape for safety reasons. When attaching the contact mat to the ground, attention was given not to compress the carpet with the tape.

The inertial sensor was attached to the waist via an apposite Velcro belt provided by Microgate (Fig.1).

The temperature of the testing room was 25 to 30°C. No smartphone, Wi-Fi, gps or other electronical devices were inside the room or within fifty meters distance from the testing area except for the laptop used for the contact mat (MacBook Pro Retina, 13-inch, Mid 2014, Intel Core i5, 2,6 GHz, 8GB RAM) which had Wi-Fi and Bluetooth switched off and the laptop used for the Gyko Repower program which only had the pen drive Bluetooth receiver switched on for data reception.

2.6 Data Processing

The variables of interest in this study were calculated from the flight-time recorded by the Chronojump and the Repower software. Data are presented as mean values and SDs.

Skewness values (inside the range between 0,5 and -0,5) and dispersion analysis showed that data follow a Gaussian curve, therefore validity of test devices were quantitatively assessed with Student's T-test for paired means, standard error of measurement

(SEM) and Pearson R-value. Furthermore, Bland-Altman plots were provided to identify the magnitude of agreements between devices [7].

Finally, Cohen's effect sizes (ES) were also calculated for all significant findings [8]. An effect size lower than 0.2 was considered trivial, from 0.3 to 0.6 small, from 0.6 to 1.2 moderate, and higher than 1.2 large. In addition, regression equations were calculated for the estimation of vertical jump height conversion from Gyko Repower data to Chronojump data and vice versa.

All analyses were performed using Microsoft Excel Statistics Package (Microsoft Office, Excel, © 2016 Microsoft Corporation). Statistical significance was set at $p < 0.05$.

## III. RESULTS

The mean values and SDs of SJ, CMJ and ABK jump height (n=96) can be observed in table 1. Pearson correlation coefficient were high for both SJ, CMJ and ABK. Student's t-test showed that p-value in all the three jump types was higher than alpha (set at 0,05).

A regression analysis was performed to look at the relationship between the Gyko and Contact Mat data (table 1).

Further (table 2), random bias (referred to a 95% CI) was detected for SJ (± 5.69 cm), CMJ (± 4.59 cm) and ABK (± 6.84 cm) height. A non-significant systematic bias of 0.24 (SJ), -0.01 (CMJ) and 0.001 (ABK) were found. Lastly, SEM value amounted to 0.63 cm (SJ), 0.69 cm (CMJ) and in 0.87 cm (ABK).

| Jump Type | Gyko Mean (SD) | Mat Mean (SD) | Pearson Correlation (r) | Student's t-test (t) | Cohen's D | Regression Equation |
|---|---|---|---|---|---|---|
| SJ | 29.83 (6.11) | 30.07 (6.23) | 0.89 | 0.42 | 0.039 | $SJ_{Mat} = 0.9079 * SJ_{Gyko} + 2.99$ |
| CMJ | 33.31 (6.60) | 33.30 (7.03) | 0.94 | 0.97 | 0.001 | $CMJ_{Mat} = 1.005 * CMJ_{Gyko} - 0.1758$ |
| ABK | 39.01 (8.57) | 39.01 (8.54) | 0.92 | 0.98 | 0.0002 | $ABK_{Mat} = 0.9132 * ABK_{Gyko} + 3.3878$ |

*Table 1*

| Jump Type | Systematic Bias [cm] | Random Bias (95% CI) [cm] | Lower LOA [cm] | Upper LOA [cm] | SEM [cm] | Observations Outside LOA [n] | Error Frequency [%] |
|---|---|---|---|---|---|---|---|
| SJ | 0.24 | 5.69 | -5.45 | 5.93 | 0.63 | 4 | 4.17 |
| CMJ | -0.01 | 4.59 | -4.60 | 4.58 | 0.69 | 7 | 7.29 |
| ABK | 0.001 | 6.84 | -6.84 | 6.85 | 0.87 | 5 | 5.21 |

*Table 2*

Figure 4a-b-c illustrate Bland-Altman plots for vertical jump height (SJ, CMJ and ABK) as assessed by the two apparatus. Those charts indicate that 4/96 (4.17 %), 7/96 (7,29 %) and 5/96 (5.21%) of the data points were beyond the mean ± 1.96 SD lines for SJ, CMJ and ABK, respectively.

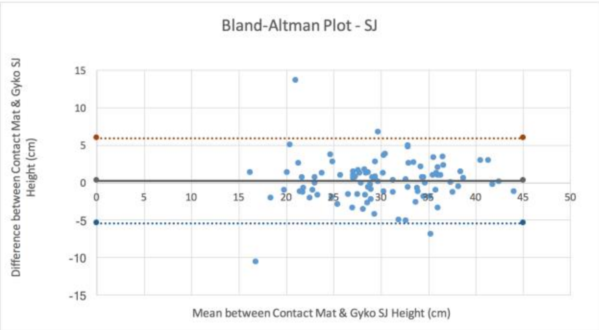


*Figure 4[a] – Bland Altman plot for the SJ data.*

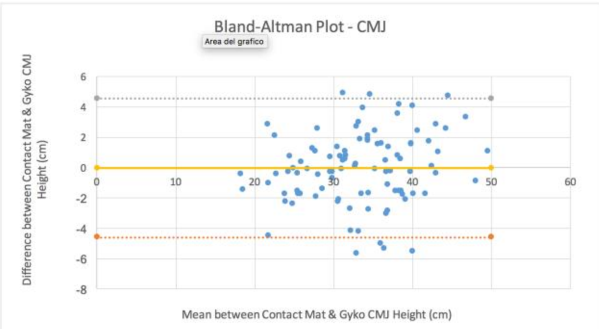


*Figure 4[b] - Bland Altman plot for the CMJ data.*

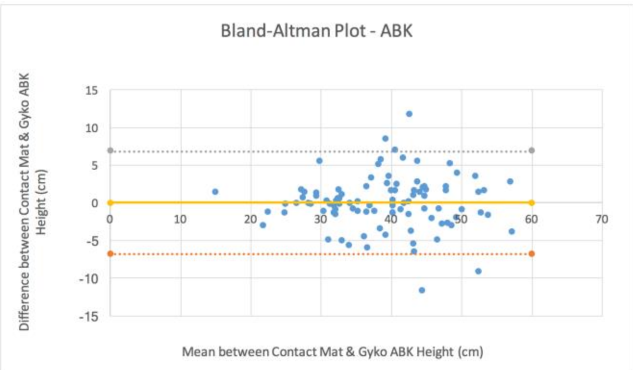


*Figure 4[c] - Bland Altman plot for the ABK data.*

Finally, it must be stated that Gyko inertial sensor failed to record 17 jumps (5,57%), therefore subjects had to repeat the jump. In any of those missed jumps the participant were endomorph (in three cases they were rugby hookers).

## IV. DISCUSSION

The present study examined concurrent validity of the Gyko inertial sensor system for the assessment of vertical jump height compared to the Chronojump contact mat (criterion device). This study, compared to the previous one investigating Gyko validity [2], has been carried out with a wider population (96, male and female vs 19, female).

The contact mat can be used interchangeably with the force platform due to its validity (Activation Sensitivity = 29,43N; Chronopic Microcontroller Sampling Rate = 1000Hz; Mean of Absolute Error = 0.1% in contact time and 0.18% in flight time) and reliability (ICCSJ = 0,998; ICCCMJ = 0,997) [1, 11] and it represent the criterion device.

In order to increase accuracy, Microgate company recommends using Gyko inertial Sensor together with the Optojump Infra-red mat for the assessment of multiple parameters (e.g. duration of eccentric phase, eccentric speed, etc.) that can't be measured with contact and infrared mat [2]. Nevertheless, according to previous literature statements [2, 3], we assumed that the Gyko system is a valid tool for the estimation of both SJ, CMJ and ABK height.

We detected non-significant systematic bias for mean SJ (0.24 cm) but CMJ (-0.01 cm) and ABK (0.001) height between the Gyko system and the Chronojump contact mat. Lesinsky et al. [2] previously reported a higher systematic bias between Gyko and Force platform (SJ: -0.91 cm; CMJ: -0.66 cm). The systematic bias we found are smaller that the previously reported in literature, this could be due to a more heterogeneous population.

Our results are not in line with those reported in the literature by the study of Castagna et al. [3]: they examined the concurrent validity of the Myotest inertial sensor system for the assessment of vertical jump flight time compared to a Kistler force-plate in male rugby players (16 ± 1 years) reporting significant systematic bias ($p < 0.001$) between the two systems. This is likely to be because we used a different model of accelerometer with higher sampling rate.

It must be stated that a high random bias (95% CI) has been found on both SJ (±5.69 cm), CMJ (±4.59 cm) and ABK (±6.84 cm) jump. This is because Gyko data are sometimes higher and sometimes lower than contact mat data. Previous research [2], state that "fixation of the Gyko system to an elastic belt produced movement artefacts which could be responsible for the high inter-/intra-individual differences in jump height between the Gyko system and the Kistler force-plate" (i.e. soft tissue artefact [16]).

"This could subsequently affect the acceleration-based determination of the exact time at take-off and landing and thus, it may distort flight time and the estimated vertical jump height".

No statistical difference has been found between $Gyko_{SJ}$ and $Mat_{SJ}$ (T-test P value: 0.42), between

$Gyko_{CMJ}$ and $Mat_{CMJ}$ (T-test P value: 0.97) and between $Gyko_{ABK}$ and $Mat_{ABK}$ (T-test P value: 0.98).

Good agreement has been found between SJ, CMJ and ABK data (Fig. 4a-b-c and Table 1). A high association has been found between $Gyko_{SJ}$ and $Mat_{SJ}$ (Pearson R-value: 0.89), $Gyko_{CMJ}$ and $Mat_{CMJ}$ (Pearson R-value: 0.94) and $Gyko_{ABK}$ and $Mat_{ABK}$ (Pearson R-value: 0.92). The magnitude of Effect Size reported by Cohen's D are low (0.039 for SJ, 0.001 for CMJ and 0.0002 for ABK), this data supports the fact that there is no statistical difference between Gyko data and Mat data.

Finally, it is possible that a less accurate measurement of SJ flight time occurs with endomorph subjects: soft tissue artefact [16] has more influence on acceleration data obtained with an inertial sensor placed on an overweight subject (i.e. the softer tissue divides the bone from the inertial sensor, the more the artefact effect is high). Further studies should investigate inertial sensor validity and reliability on this specific population, with particular attention been given to the location of the accelerometer and how tightly it is attached to the body.

## V. CONCLUSION

The present study examined concurrent validity of the Gyko inertial sensor system for the assessment of vertical jump height compared to the Chronojump contact mat (criterion device).

Briefly, the nonsignificant systematic bias, the good to excellent correlation and the lack of statistical difference we found between the two devices indicate that Gyko inertial sensor can be used interchangeably with Chronojump Contact Mat. The high random bias we found (higher than in previous study [2]) could be due to the fact that a single trial for every jump has been collected, it is suggested that three trial are performed before taking the mean value of the three, in order to decrease random error. Regression equations are available, for the sake of precision, in Table 1; those can be used for the conversion of Gyko derived data into contact mat data even if the difference is not statistically relevant.

Although this study is a landmark, based on a wider population than the previous reported in literature [2], further studies are necessary for investigating the validity and the interchangeability of Gyko inertial sensor in relation to soft tissue artefact [16] and on how to attain it with overweight subjects.

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***Availability of data and materials***

For availability of data and material please contact the corresponding author.

***Conflict of interest***

The authors declare no conflict of interest with the Microgate S.r.l (Italy, Bolzano) company and the Chronojump-BoscoSystem® (Barcelona, Spain) company.

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