THE VALIDITY AND RELIABILITY OF A NOVEL APP FOR THE MEASUREMENT OF CHANGE OF DIRECTION PERFORMANCE

Carlos Balsalobre-Fernández[1], Chris Bishop[2], José Vicente Beltrán-Garrido[3], Pau Cecilia-Gallego[3], Aleix Cuenca-Amigó[3], Daniel Romero-Rodríguez[4], Marc Madruga-Parera[3,4]

[1]Department of Physical Education, Sport and Human Movement, Autonomous University of Madrid, Spain

[2]Faculty of Science and Technology, London Sport Institute, Middlesex University, London, UK

[3]University School of Health and Sport (EUSES), University of Rovira Virgili, Amposta, Spain

[4]University School of Health and Sport (EUSES), University of Girona, Girona, Spain

Running title: iPhone app for the measurement of change of direction

Keywords: sprinting; agility; biomechanics; technology; smartphone

Word count: 2832

Carlos Balsalobre-Fernández

Department of Physical Education, Sport and Human Movement, Universidad Autónoma de Madrid, Spain

Address: C/ Fco Tomas y Valiente 3, 28049, Cantoblanco, Madrid, Spain

E-mail: carlos.balsalobre@icloud.com

Chris Bishop

Faculty of Science and Technology, London Sport Institute, Middlesex University, London, UK

Address: The Burroughs, Hendon, NW4 4BT London, United Kingdom

E-mail: C.Bishop@mdx.ac.uk

José Vicente Beltrán-Garrido

University School of Health and Sport (EUSES), University of Rovira Virgili, Amposta, Spain

Address: C/ Sebastià Joan Arbó, 2 43870 Amposta-Tarragona, Spain

E-mail: jose.vicente@euseste.es

Pau Cecilia-Gallego

University School of Health and Sport (EUSES), University of Rovira Virgili, Amposta, Spain

Address: C/ Sebastià Joan Arbó, 2 43870 Amposta-Tarragona, Spain

E-mail: pau.cecilia@euseste.es

Aleix Cuenca-Amigó

University School of Health and Sport (EUSES), University of Rovira Virgili, Amposta, Spain

Address: C/ Sebastià Joan Arbó, 2 43870 Amposta-Tarragona, Spain

E-mail: aleixcuenca@yahoo.es

Daniel Romero-Rodriguez

University School of Health and Sport (EUSES), University of Girona, Girona, Spain

Address: C/ President Francesc Macià, 65, 17190 Salt-Girona, Spain

E-mail: danirrphysco@gmail.com

Marc Madruga-Parera

University School of Health and Sport (EUSES), University of Girona, Girona, Spain

Address: C/ President Francesc Macià, 65, 17190 Salt-Girona, Spain

E-mail: marcmparera@gmail.com

Corresponding author: Carlos Balsalobre-Fernández

Department of Physical Education, Sport and Human Movement, Universidad Autónoma de Madrid, Spain

Address: C/ Fco Tomas y Valiente 3, 28049, Cantoblanco, Madrid, Spain

E-mail: carlos.balsalobre@icloud.com

Abstract

The aim of the present investigation was to analyze the validity and reliability of a novel iPhone app (CODTimer) for the measurement of total time and interlimb asymmetry in the 5+5 change of direction test (COD). To do so, twenty physically active adolescent athletes (age=13.85±1.34 years) performed six repetitions in the COD test while being measured with a pair of timing gates and CODTimer. A total of 120 COD times measured both with the timing gates and the app were then compared for validity and reliability purposes. There was an almost perfect correlation between the timing gates and the CODTimer app for the measurement of total time (r=0.964; 95% Confidence interval (CI)=0.95-1.00; Standard error of the estimate=0.03s.; p<0.001). Moreover, non-significant, trivial differences were observed between devices for the measurement of total time and interlimb asymmetry (Effect size<0.2, p>0.05). Similar levels of reliability were observed between the timing gates and the app for the measurement of the 6 different trials of each participant (Timing gates: Intraclass correlation coefficient (ICC)=0.651-0.747, Coefficient of variation (CV)=2.6-3.5%; CODTimer: ICC=0.671-0.840, CV=2.2-3.2%). The results of the present study show that change of direction performance can be measured in a valid, reliable way using a novel iPhone app.

Keywords: sprinting; agility; biomechanics; technology; smartphone

Introduction

Change of direction speed (CODS) is a critical component of athletic performance and its importance has been well documented in many sports. For example, it has been suggested that soccer players can perform 1200-1400 changes of direction in a game (Bangsbo, 1992), that CODS is a crucial for both rugby league and union athletes of all standards (Baker & Newton, 2008; Delaney et al., 2015; Gabbett, Kelly, & Sheppard, 2008), and even fencers can cover as much as 1000 m with up to 200 changes of direction during elimination bouts (Turner et al., 2016). Thus, with CODS being such a prominent physical quality during competition, it is no surprise that it is often included in fitness testing batteries for the assessment of athletic performance (Baker & Newton, 2008; Chaouachi et al., 2012; Cooke, Quinn, & Sibte, 2011; Nimphius, Callaghan, Bezodis, & Lockie, 2018).

When measuring CODS, several timing-based technologies have been used in the literature such as electronic timing gates, infrared photo-beam cells, radar guns and stop watches (Haugen & Buchheit, 2016; Morin, 2013; Samozino et al., 2015), with electronic timing gates often considered as the gold standard instrument to measure time events (Sheppard & Young, 2006). However, one key drawback of this technology is its high cost. This prevents its use to coaches and institutions where budgets are limited. Solving these limitations, smartphone applications (apps) have been proved to be a valid, reliable and accurate alternative to traditional laboratory equipment for the measurement of several physical capabilities like vertical jumping (Balsalobre-Fernández, Glaister, & Lockey, 2015; Haynes, Bishop, Antrobus, & Brazier, 2018), barbell velocity (Balsalobre-Fernández, Marchante, Muñoz-López, & Jiménez, 2018; Pérez-Castilla, Piepoli, Delgado-García, Garrido-Blanca, & García-Ramos, 2019) or linear running and sprinting (Balsalobre-Fernández, Agopyan, &

Morin, 2017; Romero-Franco et al., 2017) thanks to the built-in slow-motion cameras present in current devices that can record at 240 frames per second. Moreover, the validity of some slow-motion apps has been confirmed in different populations like adolescent athletes (Rogers et al., 2019), old adults (Cruvinel-Cabral et al., 2018) or even professional Cerebral palsy players (Coswig et al., 2019). However, to date no app has been developed to specifically measure CODS performance.

Therefore, the aim of the present investigation was to test the concurrent validity and reliability of a novel iOS app (named: *CODTimer*) that was specifically designed to measure the total time and interlimb asymmetry in the 5+5 change of direction test (i.e., a 180º COD task) (Nimphius et al., 2018) in adolescent athletes. Based on previous literature that analyzed the validity of slow-motion apps to measure linear running and sprinting (Balsalobre-Fernández et al., 2017; Romero-Franco et al., 2017), we hypothesize that *CODTimer* would be a valid, reliable and accurate alternative for the measurement of total time in the 5+5 test when compared with a set of electronic timing gates.

Methods

Participants

Twenty voluntary adolescent soccer players were recruited (mean (SD): age = 13.85 ± 1.34 years; height = 1.67 ± 0.45 m; body weight = 47.98 ± 7.48 kg). The study protocol complied with the Declaration of Helsinki for Human Experimentation and was approved by the ethics committee at the institutional review board. Written informed consent was obtained from each participant and their parents/legal tutors in advance.

Study design

In order to analyze the validity and reliability of the *CODTimer* mobile application, the participants performed a 5+5 180º COD test (Castillo-Rodríguez, Fernández-García, Chinchilla-Minguet, & Carnero, 2012) on an artificial outdoor grass surface. Every participant performed a total of 6 trials (3 trials with COD executed with the right lower limb and 3 trials with COD executed with the left lower limb). Time of each trial was measured by both the photocells (Witty gate) and the COD timer application simultaneously. The 120 times registered of both instruments were compared in order to perform validity and reliability analysis with statistical procedures. All tests were performed during the afternoon (6pm to 8pm) in similar temperature (23ºC) and humidity (60%) conditions.

Instruments

A single beam photocell (Witty gate, Microgate, Bolzano, Italy, http://www.microgate.it) were used as criterion variable to measure the execution time of the trials. One photocell was allocated at the start/finish gate of the test in order to quantify the time employed by the participant to perform each trial. The photocell possesses an integrated transmission system with a 150 m range and a precision of ± 0.4 ms. The radiofrequency signal was collected by the central unit via remote that interprets the start and end times of each trial. The photocell height was individually adjusted to match each athlete's ground-to-hip height.

The *CODTimer* app was specifically developed for this study using Xcode 10.2.1 for macOS High Sierra 10.14.4 and the Swift 5 programming language with iOS 12 SDK (Apple Inc., USA). The AVFoundation and AVKit frameworks (Apple Inc., USA) were used for capturing, importing and manipulating high-speed videos. Then, the app (version 1.0) was installed on an iPhone X running iOS 12.2 (Apple Inc., USA) which has a recording frequency of 240 frames per second (fps) at a quality of FullHD (1920x1080 pixels). The app's user interface was designed to record and high-speed videos and to allow a frame-by-frame inspection of them. Then, the app calculates the total time in the 5+5 change of direction test (5+5) as the difference between two time events which were manually selected by an independent user as follows: the beginning of the 5+5 was considered as the first frame in which the participant crossed the timing gate in the starting/end line of the test, and the end was considered as the first frame in which the participant crossed that gate again. A video-tutorial showing the complete procedure can be found in the following URL: https://youtu.be/_Y2xZjMA7fc.

5+5 COD test measurement

In order to record the videos, the mobile phone was attached in a tripod in vertical position. The trials were recorded from a perpendicular plane to the starting/finishing gate of the test. The mobile was placed 2 m away from the photocell position to record the instant in which any part of the participant's body crossed the starting/finishing gate of the test, interrupting the beam of the light of the photocell. See Figure 1 for more details.

** FIGURE 1 ABOUT HERE **

The start and finish of every trial was considered as the first frame in which the participant crossed the timing gate with any part of his body (specifically, when the participant crossed the imaginary line linking sender and receiver of the photocell, i.e., the infrared line that activates the timing). Once the frames were selected, the application exported the data to a spreadsheet for posterior analysis. Trained sports scientists with at least one year of experience in slow motion apps analyzed all of the videos. Previous investigations showed a very high intra-rater reliability of trained observers when analyzing slow motion (Stanton, Wintour, & Kean, 2016).

After a 10-15 min standard warm-up consisted of jogging, dynamic stretching and activation exercises of increasing intensity, the participants performed the 5+5 180º COD test (Castillo-Rodríguez et al., 2012). Starting position was standardized to all participants. The participant was in the middle of a 1.5 m lane, with a two-point staggered stance. The most advanced foot was placed 30 cm from the starting line and the other one in line with the heel of the forward foot. Each participant was instructed to perform a 10-m sprint with a 180° COD at 5 m before return to the starting point (Figure 1). All participants wore soccer boots, and they were familiar with the 5+5 COD test from their regular soccer practice.

Statistical analyses

The app's concurrent validity was tested by means of a linear regression, Pearson's *r* correlation matrix with 95% confidence intervals (CI), the standard error of the estimate (SEE), and the slope of the regression line were analyzed. To test collinearity, the Durbin-Watson test was also computed. Second, to analyze the level of agreement (reliability) between the app and the timing gates for the measurement of total time in the change of direction test, the intraclass correlation coefficient with 95% CI (ICC, two-way random, absolute agreement). ICC was interpreted as follow: ICC > 0.9 = excellent, 0.75-0.9 = good, 0.5-0.74 = moderate, < 0.50 = poor (Koo & Li, 2016). Also, paired samples *t*-test and Bland-Altman plots were used to identify potential systematic bias, reported via mean bias, standard deviations and the analysis of the regression line on the Bland–Altman plots. If some variables failed to comply with the normality and homogeneity assumptions (which were computed using Shapiro-Wilk and Levene's tests), Mann-Whitney U-test was used to test the difference between variables. The standardized mean difference (SMD) between the measures obtained with each instrument was calculated using Cohen's *d* effect size and reported as trivial (0-0.2), small (0.2-0.6), moderate (0.6-1.2) or large (>1.2) (Rhea, 2004). When analyzing the reproducibility of the *CODTimer* app for the measurement of the 3 different trials conducted with each leg, the coefficient of variation (CV) was used. The level of significance was set at 0.05. Inter-limb asymmetries were calculated using the following equation:

100 - (100 / maximum value) * minimum value.

All calculations were performed using JASP 0.9.2 for Mac (University of Amsterdam, Netherlands).

Results

Concurrent validity

The analysis of the whole dataset (i.e., 120 individual points) showed a very high correlation between the *CODTimer* app and the timing gates (TG) for the measurement of the total time in the change of direction test (r = 0.964; 95% CI = 0.95-1.00; SEE = 0.03 s.; Slope of the regression line = 0.998; p < 0.001). No collinearity was observed as revealed by the Durbin-Watson test (d = 2.10) (Figure 2).

** FIGURE 2 ABOUT HERE **

Non-significant, trivial differences were observed in the total time of the change of direction test between the *CODTimer* app and the TG (Mean difference = -0.02 ± 0.03 s.; ES = -0.19; 95% CI = -0.46 to 0.06; p = 0.14). The analysis of the Bland-Altman plot showed a systematic bias between the *CODTimer* app and the TG for the total time (Bias = 0.02 s.; 95% CI = 0.01 to 0.03 s.; Lower limit of agreement = -0.04 s.; Upper limit of agreement = 0.09 s.). Finally, the regression line in the Bland-Altman plot showed no heteroscedasticity in the distribution of the difference between devices as revealed by its regression line (r^2 = 0.014). See Figure 3.

** FIGURE 3 ABOUT HERE **

Reliability

The ICC showed a very high agreement between the *CODTimer* app and the TG for the measurement of total time in the change of direction test (ICC = 0.97; 95% CI = 0.90 to 0.99). When analyzing the reproducibility of the *CODTimer* app for the measurement of 3 different trials with each leg, similar levels of reliability were observed in comparison with those obtained with the TG (TG left leg: CV = 3.5 ± 2.2 %, ICC = 0.651, 95% CI = 0.266 to 0.851; TG right leg: CV = 2.6 ± 1.3 %, ICC = 0.747, 95% CI = 0.467 to 0.892; *CODTimer* left leg: CV = 3.2 ± 2.3 % ICC = 0.671, 95% CI = 0.306 to .859, *CODTimer* right leg: CV = 2.2 ± 1.0 %, ICC = 0.840, 95% CI = 0.663 to 0.932). Non-significant differences were observed between the CV calculated with the *CODTimer* app and the TG (ES < 0.2, p > 0.05). See Figure 4.

** FIGURE 4 ABOUT HERE **

Measurement of interlimb asymmetry

Finally, trivial, non-significant differences were observed in the inter-limb asymmetries in the change of direction tests between devices (timing gates = 1.67 ± 1.65%; *CODTimer* = 1.70 ± 1.16%; ES = 0.13; 95% CI = -0.22 to 0.45; p = 0.50).

Discussion

The primary aim of the present study was to test the concurrent validity and reliability of a novel iOS app (named: *CODTimer*) that was specifically designed to measure the total time in the 5+5 change of direction test. Results in our study showed that the *CODTimer* app is highly valid and reliable for the measurement of the total time in the 5+5 change of direction test in adolescent soccer players. Additionally, similar interlimb asymmetry scores were obtained with the app in comparison with the timing gates (ES < 0.2, p> 0.05).

Specifically, the linear regression analysis showed a very high association (r^2 = 0.93) between the app and the timing gates, with a slope coefficient very close to the identity line (Slope = 0.998). Moreover, no collinearity was observed as revealed by the Durbin-Watson test (d = 2.1). When different measures from a same participant are included in a regression model, collinearity might occur, producing overestimations of the fit (Naclerio & Larumbe-Zabala, 2018). Even if six trials from the same participant were included, it did not affect the fit of the linear regression model. Trivial, non-significant differences were observed between the total time/completion times measured with the app and the timing gates (ES < 0.2; p > 0.05). These results are in line with previous research that analyzed the ability of a slow-motion app for the measurement of time events during a 30-m. sprint, were very high associations were observed between the app and the timing gates (r^2 > 0.97), with no significant differences between devices (Romero-Franco et al., 2017). Thus, when compared to electronic timing gates, the *CODTimer* can be considered as a valid and cost-effective alternative for practitioners who are looking to measure total time during the 5+5 test.

Determining the reliability of the *CODTimer* app was another aim of the present study and the results show that the app is highly reliable. Relative reliability (as reported by the ICC) was moderate on both limbs when calculated from the timing gates (ICC = 0.651-0.747), whilst the *CODTimer* reported moderate reliability on the left limb (ICC = 0.671), but good reliability on the right limb (ICC = 0.840). In addition, the ICC was also used to compare the agreement between the timing gates and app and showed near perfect reliability (ICC = 0.97). When considering absolute reliability using the CV, similar and acceptable values of reliability were observed with both devices, with CVs ranging from 2.2-3.2% for the app, and 2.6-3.5% for timing gates. Previous research has highlighted that CV values < 10% are considered acceptable (Cormack, Newton, McGuigan, & Doyle, 2008). Thus, practitioners can have confidence that the *CODTimer* is a reliable method for measuring total time during the 5+5 test.

Another feature of the 5+5 test is the ability to detect inter-limb asymmetry scores, regardless of whether the app or timing gates were used. Results showed comparable asymmetry values between test methods (timing gates = 1.67 ± 1.65%; *CODTimer* = 1.70 ± 1.16%), which is unsurprising given that both test methods reported very similar test variability. However, it is worth noting that the mean asymmetry scores from the 5+5 test can be considered very small (Bishop, Turner, & Read, 2017). Previous research has suggested that the use of total time as a metric to detect inter-limb differences is poor (Dos'Santos, Thomas, Jones, & Comfort, 2018; Madruga-Parera et al., 2019) and the asymmetry results in the present study would appear to support such a suggestion. Recently, when aiming to measure asymmetry during CODS tasks, it has been suggested that the change of direction deficit (CODD) could be a more useful tool (Dos'Santos et al. 2018). The CODD subtracts an athlete's linear speed time (e.g., 10-m) from a CODS time of equivalent distance (e.g., 5+5 test) and has been suggested to better isolate the change of direction component in a CODS test (Nimphius et al. 2018). Dos'Santos et al. (2018) reported mean asymmetry values for total time of -2.3% during the 505 test, but -11.9% for the CODD within the same test in 43 youth netball players. Thus, if practitioners wish to profile an athlete's between-limb differences, it is suggested that using the CODD could be a more sensitive measure of detecting inter-limb asymmetries. However, it is worth noting that in order for this to be achieved, a linear speed test of comparable distance would also need to be measured. As with COD, linear sprint can be measured in a valid and reliable way using a smartphone app (Romero-Franco et al., 2017).

Despite the novelty and usefulness of the present study, there is one key limitation which should be acknowledged. Firstly, the results of the present study can be applied only to the 5+5 test (i.e., a 180º COD task). Future research should aim to determine the reliability of the *CODTimer* app across multiple CODS tests, such as the 505, pro-agility or even cutting tasks like 90º COD. Practitioners may have specific requirements or preferences when measuring CODS performance; thus, this would increase the usability of the app in the field.

In conclusion, the *CODTimer* app was shown to be a highly valid and reliable tool to measure total time in the 5+5 180º COD test in adolescent soccer players. Additionally, it was shown that the app was able to detect interlimb asymmetries with small, non-significant differences in comparison with timing gates. The present investigation adds to the literature by showing that slow-motion video analysis can be a valid and reliable alternative for the measurement of very short, 180º CODS tests.

Acknowledgements

The authors want to thank the athletes for their involvement in the present study.

Disclosure statement

The first author of the article is the developer of the app mentioned. The data from the app were obtained from an independent observer not related to the app's development.

References

Baker, D. G., & Newton, R. U. (2008). Comparison of Lower Body Strength, Power, Acceleration, Speed, Agility, and Sprint Momentum to Describe and Compare Playing Rank among Professional Rugby League Players. *Journal of Strength and Conditioning Research*, *22*(1), 153–158. https://doi.org/10.1519/JSC.0b013e31815f9519

Balsalobre-Fernández, C., Agopyan, H., & Morin, J.-B. (2017). The Validity and Reliability of an iPhone App for Measuring Running Mechanics. *Journal of Applied Biomechanics*, *33*(3), 222–226. https://doi.org/10.1123/jab.2016-0104

Balsalobre-Fernández, C., Glaister, M., & Lockey, R. A. (2015). The validity and reliability of an iPhone app for measuring vertical jump performance. *Journal of Sports Sciences*, *33*(15), 1574–1579. https://doi.org/10.1080/02640414.2014.996184

Balsalobre-Fernández, C., Marchante, D., Muñoz-López, M., & Jiménez, S. L. (2018). Validity and reliability of a novel iPhone app for the measurement of barbell velocity and 1RM on the bench-press exercise. *Journal of Sports Sciences*, *36*(1), 64–70. https://doi.org/10.1080/02640414.2017.1280610

Bangsbo, J. (1992). Time and motion characteristics of competitive soccer. *Sci Football*, *6*, 34–42.

Bishop, C., Turner, A., & Read, P. (2017). Effects of inter-limb asymmetries on physical and sports performance: a systematic review. *Journal of Sports Sciences*, 1–10. https://doi.org/10.1080/02640414.2017.1361894

Castillo-Rodríguez, A., Fernández-García, J. C., Chinchilla-Minguet, J. L., & Carnero, E. Á. (2012). Relationship Between Muscular Strength and Sprints with Changes of Direction. *Journal of Strength and Conditioning Research*, *26*(3), 725–732. https://doi.org/10.1519/JSC.0b013e31822602db

Chaouachi, A., Manzi, V., Chaalali, A., Wong, D. P., Chamari, K., & Castagna, C. (2012). Determinants Analysis of Change-of-Direction Ability in Elite Soccer Players. *Journal of Strength and Conditioning Research*, *26*(10), 2667–2676. https://doi.org/10.1519/JSC.0b013e318242f97a

Cooke, K., Quinn, A., & Sibte, N. (2011). Testing Speed and Agility in Elite Tennis Players. *Strength and Conditioning Journal*, *33*(4), 69–72. https://doi.org/10.1519/SSC.0b013e31820534be

Cormack, S. J., Newton, R. U., McGuigan, M. R., & Doyle, T. L. A. (2008). Reliability of Measures Obtained during Single and Repeated Countermovement Jumps. *International Journal of Sports Physiology and Performance*, *3*(2), 131–144. https://doi.org/10.1123/ijspp.3.2.131

Coswig, V., Silva, A. D. A. C. E., Barbalho, M., Faria, F. R. De, Nogueira, C. D., Borges, M., … Gorla, J. I. (2019). Assessing the Validity of the MyJump2 App for Measuring Different Jumps in Professional Cerebral Palsy Football Players: An Experimental Study. *JMIR MHealth and UHealth*, *7*(1), e11099. https://doi.org/10.2196/11099

Cruvinel-Cabral, R. M., Oliveira-Silva, I., Medeiros, A. R., Claudino, J. G., Jiménez-Reyes, P., & Boullosa, D. A. (2018). The validity and reliability of the " My Jump App " for measuring jump height of the elderly. *PeerJ, 6*, e5804. https://doi.org/10.7717/peerj.5804

Delaney, J. A., Scott, T. J., Ballard, D. A., Duthie, G. M., Hickmans, J. A., Lockie, R. G., & Dascombe, B. J. (2015). Contributing Factors to Change-of-Direction Ability in Professional Rugby League Players. *Journal of Strength and Conditioning Research*, *29*(10), 2688–2696.

https://doi.org/10.1519/JSC.0000000000000960

Dos'Santos, T., Thomas, C., Jones, P. A., & Comfort, P. (2018). Assessing Asymmetries in Change of Direction Speed Performance; Application of Change of Direction Deficit. *Journal of Strength and Conditioning Research*, 1. https://doi.org/10.1519/JSC.0000000000002438

Gabbett, T. J., Kelly, J. N., & Sheppard, J. M. (2008). Speed, Change of Direction Speed, and Reactive Agility of Rugby League Players. *Journal of Strength and Conditioning Research*, *22*(1), 174–181. https://doi.org/10.1519/JSC.0b013e31815ef700

Haugen, T., & Buchheit, M. (2016). Sprint Running Performance Monitoring: Methodological and Practical Considerations. *Sports Medicine (Auckland, N.Z.)*, *46*(5), 641–656. https://doi.org/10.1007/s40279-015-0446-0

Haynes, T., Bishop, C., Antrobus, M., & Brazier, J. (2018). The validity and reliability of the my jump 2 app for measuring the reactive strength index and drop jump performance. *The Journal of Sports Medicine and Physical Fitness*. https://doi.org/10.23736/S0022-4707.18.08195-1

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine*, *15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Madruga-Parera, M., Romero-Rodríguez, D., Bishop, C., Beltran-Valls, M. R., Latinjak, A. T., Beato, M., & Fort-Vanmeerhaeghe, A. (2019). Effects of Maturation on Lower Limb Neuromuscular Asymmetries in Elite Youth Tennis Players. *Sports*, *7*(5), 106. https://doi.org/10.3390/sports7050106

Morin, J.-B. (2013). Sprint Running Mechanics: New Technology, New Concepts, New Perspectives. *Aspetar Sports Medicine Journal*, *2*(3), 326–332.

Naclerio, F., & Larumbe-Zabala, E. (2018). Technical Note on Using the Movement Velocity to Estimate the Relative Load in Resistance Exercises – Letter to the Editor. *Sports Medicine International Open*, *02*(01), E16–E16. https://doi.org/10.1055/s-0043-118710

Nimphius, S., Callaghan, S. J., Bezodis, N. E., & Lockie, R. G. (2018). Change of Direction and Agility Tests. *Strength and Conditioning Journal*, *40*(1), 26–38. https://doi.org/10.1519/SSC.0000000000000309

Pérez-Castilla, A., Piepoli, A., Delgado-García, G., Garrido-Blanca, G., & García-Ramos, A. (2019). Reliability and concurrent validity of seven commercially available devices for the assessment of movement velocity at different intensities during the bench press. *Journal of Strength and Conditioning Research*. https://doi.org/10.1519/JSC.0000000000003118

Rhea, M. R. (2004). Determining the magnitude of treatment effects in strength training research through the use of the effect size. *Journal of Strength & Conditioning Research*, *18*(4), 918–920. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,cookie,url,uid&db=s3h&AN=15256290&lang=es&site=ehost-live

Rogers, S. A., Hassmén, P., Hunter, A., Alcock, A., Crewe, S. T., Strauts, J. A., … Weissensteiner, J. R. (2019). The Validity and Reliability of the MyJump2 Application to Assess Vertical Jumps in Trained Junior Athletes. *Measurement in Physical Education and Exercise Science*, *23*(1), 69–77. https://doi.org/10.1080/1091367X.2018.1517088

Romero-Franco, N., Jiménez-Reyes, P., Castaño-Zambudio, A., Capelo-Ramírez, F., Rodríguez-Juan, J. J., González-Hernández, J., … Balsalobre-Fernández, C. (2017). Sprint performance and mechanical outputs computed with an iPhone app: Comparison with existing reference methods. *European Journal of Sport Science*, *17*(4), 386–392. https://doi.org/10.1080/17461391.2016.1249031

Samozino, P., Rabita, G., Dorel, S., Slawinski, J., Peyrot, N., Saez de Villarreal, E., & Morin, J.-B. (2015). A simple method for measuring power, force, velocity properties, and mechanical effectiveness in sprint running. *Scandinavian Journal of Medicine & Science in Sports*. https://doi.org/10.1111/sms.12490

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. *Journal of Sports Sciences*, *24*(9), 919–932. https://doi.org/10.1080/02640410500457109

Stanton, R., Wintour, S.-A., & Kean, C. O. (2016). Validity and intra-rater reliability of MyJump app on iPhone 6s in jump performance. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2016.09.016

Turner, A., Bishop, C., Chavda, S., Edwards, M., Brazier, J., & Kilduff, L. P. (2016). Physical Characteristics Underpinning Lunging and Change of Direction Speed in Fencing. *Journal of Strength and Conditioning Research, 30*(8), 2235–2241. https://doi.org/10.1519/JSC.0000000000001320

FIGURE CAPTIONS

Figure 1. Schematic representation of the 5+5 change of direction test, showing were the timing gates and the smartphone were placed. A supplemental video showing how to use the app to analyze the test can be found in the following URL: https://youtu.be/_Y2xZjMA7fc

Figure 2. Linear regression between the *CODTimer* app and the timing gates for the measurement of total time in the change of direction test.

Figure 3. Bland-Altman plot showing the bias (with 95% CI) between instruments, its limits of agreement (±1.96 standard deviations), and the regression line of the residual (bold grey line). Overlapping points are represented with wider circles.

Figure 4. Boxplots with jitter points for the CVs of the different trials performed with each leg, and each instrument.