

Within-session reliability and criterion validity of ADR Jumping photocell in the estimation of CMJ

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Abstract:

Vertical jump height is a key measure of lower limb power and performance in many sports and athletic activities. Accurate measurement of vertical jump height is essential to monitor progress, set goals, and design training programs. Besides, new more economical and manageable instruments are emerging. However, it is necessary to know if these devices can measure with the required precision and accuracy. This study examines the concordance (criterion validity) between a new portable photocell ADR jumping and the jump mat Chronojump. Additionally, the within-session test-retest reliability (internal consistency) of CMJ was studied. Twelve highly trained female volleyball players (age: 21.7 ± 2.9 years; height: 1.73 ± 0.06 m; body mass 64.3 ± 7.6 kg; body mass index (BMI): 16.6 ± 2.5 kg/cm²; training experience 8.5 ± 1.8 y). Following a standardized warm-up and a resting period of 5 minutes, 10 CMJs were executed, resting for 2 minutes for each attempt. All records were collected simultaneously by the ADR jumping photocell and the Chronojump Jump mat to compare data from both devices. The within-session test-retest reliability was evaluated using the first three jumps of all participants. The agreement between devices was near-perfect ($r = 0.95$; CCC = 0.94; SEM = 1.47 cm; Regression Slope=0.99). However, significant differences were detected between instruments (0.81 cm $p < 0.05$, ES = 0.2). Within-session reliability was slightly higher in ADR jumping (ICC = 0.93; CCC = 0.90; SEM = 1.3 cm; CV = 4.89%) than Chronojump (ICC = 0.91; CCC = 0.87; SEM = 1.6 cm; CV = 6.0%). Furthermore, sensitivity was higher for ADR jumping (SWC = 0.37 cm) than for the Chronojump (SWC = 0.45 cm). The noise of the measurement (SEM) was greater than the worthwhile change (SWC), indicating a lack of capacity to detect meaningful changes. In conclusion, the ADR jumping photocell is a valid instrument when compared to the Chronojump jump mat in the measurement of CMJ. In addition, ADR jumping shows high internal consistency values, therefore, can be considered a reliable device for the within-session test-retest in the measurement of CMJ in highly trained female athletes.

Key Words: consistency, test-retest, concordance, vertical jump, sensibility, error.

Introduction

Vertical jump (VJ) height is a key measure of lower limb power and performance in many sports and athletic activities (Merino-Muñoz et al., 2021; Rantalainen et al., 2020), since a greater jump height may imply a possibility of achieving better sports performance (Pawlik & Mroczek, 2023). Accurate measurement of VJ height is essential for athletes, coaches, and trainers to monitor progress, set goals, and design training programs (Washif & Kok, 2021; Watkins et al., 2017). The use of force platforms and motion capture technology is considered the gold standard in the evaluation of VJ. However, their use is usually restricted due to their excessive economic cost and the difficulties involved in handling and putting them into use (Alba-Jiménez et al., 2022). For this reason, new cheaper, portable and easier-to-use devices have emerged on the market in the last years, such as Inertial measurements units which are based on the detection of the takeoff velocity (Jimenez-Olmedo, Pueo, et al., 2023; McCurdy et al., 2022), linear transducers (Hojka et al., 2022), camera-based applications for smartphone or tablet devices (Balsalobre-Fernández et al., 2014), as well as contact mats (Pojskic et al., 2022; Pueo et al., 2017) and photocells or laser beam specially designed for VJ estimation such as the Optojump device (Microgate, Bolzano, Italy) (Nogueira et al., 2020; Peña García-Orea et al., 2018; Yıldız & Fidan, 2020), Ergojump plus or IR-mat (García-López et al., 2013).

Traditionally, jump mats have been one of the most used tools for measuring VJ height (Pojskic et al., 2022). They are relatively easy to use, portable and provide a quick and simple measurement of jump height. These systems can estimate jump height from flight time (FT) where FT is the time between takeoff and landing, proving to be valid and reliable instruments (Pueo et al., 2018). However, jump mats have several limitations one of these limitations is the variation in ankle flexion during landing and take-off or foot size may affect the validity of the instrument (Wade et al., 2020). The reliability of the contact mats can also be affected by an inconsistency in the homogeneity along the entire contact surface when detecting the forces to activate the

circuits that detect the takeoff and landing moments (Xu et al., 2023). Also, its validity is affected by the appearance of systematic error, especially when compared with devices that estimate the VJ with other methods such as double integration, tracking a marker with motion capture or detecting the takeoff velocity (Fernandes et al., 2021; Rantalainen et al., 2020). Nevertheless, some of these limitations are not exclusive to jump mats and affect all FT-based devices such as photocells, accelerometers, and photogrammetry-based systems. Otherwise, they do not provide information about the athlete's take-off velocity or kinetic variables. However, despite these limitations, the jump mats have been used as a criterion element to compare the validity of instruments for the measurement of VJ, given their high precision and reliability that has been demonstrated in comparison with force platforms and motion capture systems (González-Conde et al., 2022).

Regarding photocells, as was the case of the jump mats, photocells can estimate jump height through the FT, which is determined by a circuit that is activated and deactivated when the infrared/laser beam is cut (García-López et al., 2013). Several studies have investigated the validity and reliability of photocell devices for measuring VJ height. Overall, the results suggest that photocell devices provide a highly accurate and reliable method for measuring jump height, with high correlations with force plates and motion capture systems (Attia et al., 2017; Glatthorn et al., 2011; Peña García-Orea et al., 2018; Yıldız & Fidan, 2020). Additionally, are appearing a new brand of photocells specially designed for estimating the VJ, those still being low-cost and portable systems, allowing data collection on real playing surfaces, such as floating parquet, synthetic surfaces, grass, etc. adding more ecological value to the data obtained (Attia et al., 2017). Despite all these advantages, photocells are still FT-based instruments, and therefore, subject to the same problems as other FT-based devices such as contact mats or photogrammetry (Xu et al., 2023).

The new ADR jumping infrared-based photocell represents one of these new economic devices designed specifically to estimate the jump height on all types of surfaces since it can be easily transported, it works with batteries and the data can be exported via Bluetooth to a smartphone or tablet with a free app installed.

Previous studies found a difference of 6% in vertical height when the photocells SportJump System Pro (DSD, Inc., León, Spain) and ErgoJump Plus (Bosco System, Byomedic SCP, Barcelona, Spain) were compared to the jump mat SportJump-v1.0 (García-López et al., 2013). On the other hand, the correlations between the wheeler photosensor (Wheeler Sports Tech, Tampa, USA) and the jump mats found by Patiño-Palma et al. (2022) were very high ($r = 0.996$) showing differences between devices of 2.5 cm, concluding that the Wheeler photocell is a reliable tool in the VJ estimation. However, if the question focuses on the ADR photocell, a large systematic error of 10.6 cm is appreciated when the photocell is compared with a motion capture system (Villalon-Gasch et al., 2023), although, given the nature of this error, it can be corrected with the pertinent adjustment equations. Moreover, González-Conde et al. (2022) compared ADR jumping with the Chronojump jumping mat, obtaining high correlations ($r = 0.98$) between the two devices, also they found high intersession reliability with intraclass correlation coefficients (ICC) of 0.89. However, in the study, the internal consistency of consecutive trials of ADR jumping was not studied.

They focused on the analysis of reliability between sessions which can be drastically affected by biological variability due to the time between sessions (Claudino et al., 2017). Thus, the internal consistency of the instrument must be investigated, minimizing as possible the effects on the experimental conditions of the subjects, which may be derived from the performance of two tests separated by a week or more.

Therefore, the purpose of this paper was to analyze the existence of concordance when confronting the values of jump with a countermovement (CMJ) height from a device (Chronojump) that has already been previously validated (criterion validity), against the ADR jumping photocell. In addition, it was intended to study the reliability, understood as internal consistency in the within-session test-retest values of both instruments in a comparative way, to make scientific use of the ADR jumping photocell.

Material & methods

Participants

The sample was composed of 12 highly trained (McKay et al., 2022) female volleyball players (age: 21.7 ± 2.9 years; height: 1.73 ± 0.06 m; body mass 64.3 ± 7.6 kg; body mass index (BMI): 16.6 ± 2.5 kg/cm²; training experience 8.5 ± 1.8 y) participating in the Spanish Superliga 2 league. Subjects were instructed to conduct normal dietary habits. Before participation, all participants were informed about the aims of the study, the experimental protocol, and the procedures of the study and voluntarily gave written informed consent to participate. The Ethics Committee at the University of Alicante approved this study (IRB No. UA-2018-11-17) in accordance with the Declaration of Helsinki of The World Medical Association.

Procedure

The procedure consisted of two sessions. In the first session, a familiarization procedure with the CMJ tests and protocols was performed, in addition, anthropometric measurements of all the participants were carried out. The data collection was carried out in the second session following a repeated measures protocol.

Test protocol

Before the jump trials, all participants made a standardized warm-up consisting of five minutes of soft running followed by three minutes of dynamic range of motion drills, and two minutes of free CMJ, in which participants reviewed the jumping protocols. Next to warm up, a resting period of 5 minutes was followed. Lastly, 10 CMJs were executed, resting two minutes for each attempt to prevent fatigue effects (Read, 1997). CMJ was performed starting from the standing position with the hands in the akimbo position and, after an auditory signal, each subject made a knee flexion prior to jumping to reach the maximum height. Jumps were considered valid if they were completed inside the jump mat limits, with a simultaneous landing phase, landing on tiptoe, and, without separating the hands from the iliac crests at any phase of the jump. In addition, the athletes were instructed to take off and land in such a way that the photocell beam cut the foot in the forefoot (Jimenez-Olmedo, Penichet-Tomas, et al., 2023). All records were collected simultaneously by the ADR jumping photocell and the Chronojump Jump mat to compare data from both devices. The within-session test-retest reliability (consistency) was evaluated using the first three jumps of all participants. To complete this analysis, the pairings of each of the consecutive jumps were analyzed, in conjunction with the mean of the test for the two devices.

Instruments

ADR jumping is a photocell containing two boxes. One of the boxes is an emitter of an Infrared beam (IR), and the second acts as a receiver. The data is sent via Bluetooth to a tablet where it is recorded using the ADR jumping application. This time will be considered as the FT. The Chronojump jump mat consisted of a rigid contact mat made of two isolated electrical plates in an open circuit configuration that is closed when a subject stands on the mat (Pueo et al., 2017). Both instruments estimated hump height from FT according to the equation $\text{Jump height} = (\text{FT})^2 \cdot g/8$, where g is gravity acceleration (9.8 m/s^2).

Statistical analysis

Descriptive data are reported as mean and 95% confidence limits. A Kolmogorov-Smirnov test was used to study normality used, which resulted in a normal distribution. Therefore, Lin's concordance index (CCC) was calculated to assess the level of agreement and the presence of systematic error between the two methods (Lin et al., 2002). The results obtained are categorized as poor (≤ 0.9), moderate (0.90–0.95), substantial (0.95–0.99) and near perfect (≥ 0.99) (McBride, 2005). Additionally, a correlation analysis was conducted by computing Pearson's bivariate correlation coefficient (r). The following thresholds were used for the interpretation of r : trivial (≤ 0.1), low (0.1–0.3), moderate (0.3–0.5), high (0.5–0.7), very high (0.7–0.9) and almost perfect (≥ 0.9) (Lake et al., 2018).

The presence of a linear association between the paired data obtained from both instruments was assessed using regression analysis. The calculation of standard error of estimate (SEE) was also carried out to check device accuracy. The t -test for paired samples was applied to determine the existence of significant differences between devices (systematic error). The effect size (ES) of the differences was determined as Hedges' corrected effect size g , interpreted as trivial (< 0.19), small (0.2 – 0.59), moderate (0.6 – 1.19), large (1.2 – 1.99), very large (2.0 – 3.99) and huge (> 4.0) (Hopkins et al., 2009).

The degree of agreement between the two instruments and successive attempts was checked using Bland-Altman plots, letting to the determination of the systematic error and its limits of agreement for 95% ($\text{LoA} = 1.96 \times \text{SD}$). To determine if there were random errors and proportional bias between methods, the bivariate Pearson's product-moment correlation coefficient of the differences was calculated, where an r^2 value greater than 0.1 would indicate their presence. The intraclass correlation coefficient (ICC) was used to determine the within-session reliability. An estimation of the error magnitude was obtained through the standard error of measurement (SEM). The coefficient of variation (CV) was calculated to establish relative reliability. A method was considered reliable if $\text{ICC} > 0.90$ and $\text{CV} < 5\%$ (Hopkins, 2000). The sensibility of the measurement was estimated by the smallest worthwhile change (SWC).

The data analysis was run utilizing MedCalc Statistical Software (v 20.100, MedCalc Software Ltd, Ostend, Belgium).

Results

Agreement between ADR and Chronojump

Table 1 shows the descriptive results of jump heights from both instruments. Also, the difference between devices is shown. Statistically significant differences were observed for jump height between ADR jumping and Chronojump with small ES. Furthermore, it can be observed a near-perfect correlation and a moderate concordance.

Table 1. Mean, the difference of means, Pearson's correlations, and agreement of ADR jumping and Chronojump.

	Chronojump	ADR	Difference	ES (g)	r	CCC
Jump height (cm)	26.89	27.71	0.81 *	0.2 (small)	0.95	0.94
95%CI	26.18 to 27.62	27.01 to 28.40	0.59 to 1.03	0.18 to 0.23	0.93 to 0.97	0.90 to 0.95

* Statistically significant difference ($p < 0.05$), CI = confidence interval, ES = Hedges' corrected effect size, r = Pearson's bivariate correlation coefficient.

Observation of the Bland Altman plot (Figure 1, a) shows a systematic error between devices of 0.81 cm. Additionally. The existence of proportional error was not appreciated ($R^2 < 0.1$). On the other hand. The regression analysis carried out (Figure 1 (b)) shows a SEE of 1.2 cm. A near-perfect positive linear association.

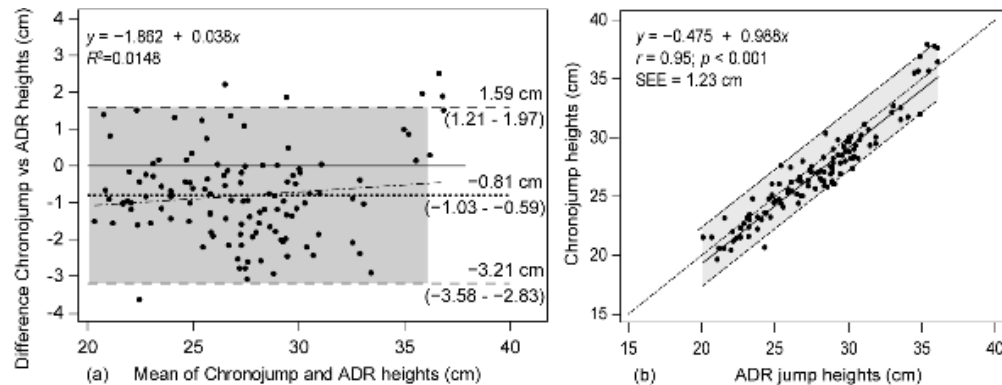


Figure 1. (a) Bland–Altman plot for the study of the grade of concordance in the jump height obtained between ADR jumping versus a Chronojump. Dotted line: the mean of the differences; shaded areas: confidence intervals for 95% of the mean and LoA; continuous line: the line of perfect agreement; plots and dashed line: the regression line of differences.

(b) Correlation analysis between the ADR jumping and Chronojump. Solid line: regression; shaded area: 95% confidence intervals of the regression line; dotted line: $x=y$ line; r : Pearson's correlation coefficient; SEE= Standard Error of Estimate.

Within-session test-retest reliability

As can be observed in Table 2. The correlation and agreement values are very high between attempts, although a high error is appreciated that could affect the sensitivity of the instrument.

Table 2. Within-session test-retest reliability for the Chronojump jump mat and the ADR jumping photocell

	Chronojump				ADR jumping			
	2–1	3–2	1–3	Mean	2–1	3–2	3–1	Mean
Change in mean	0.87	0.24	-1.1	–	0.74	0.21	-0.95	–
CI-95% lower	-0.05	-1.06	-2.3	–	-0.27	-0.86	-1.73	–
CI-95% upper	1.80	1.54	0.15	–	1.75	1.29	-0.17	–
ICC	0.94	0.87	0.89	0.91	0.92	0.91	0.95	0.93
CI-95% lower	0.85	0.66	0.73	0.81	0.80	0.76	0.87	0.81
CI-95% upper	0.98	0.95	0.96	0.96	0.97	0.97	0.98	0.97
CCC	0.91	0.84	0.85	0.87	0.89	0.89	0.92	0.90
CI-95% lower	0.76	0.53	0.57	0.62	0.68	0.66	0.76	0.70
CI-95% upper	0.97	0.94	0.88	0.93	0.95	0.99	0.97	0.97
ρ (precision)	0.94	0.83	0.88	0.88	0.91	0.89	0.94	0.88
C_b (accuracy)	0.97	0.99	0.96	0.97	0.98	0.99	0.97	0.98
SEM (cm)	1.26	1.77	1.72	1.60	1.38	1.47	1.07	1.32
CI-95% lower	0.94	1.32	1.29	1.32	1.03	1.10	0.80	1.09
CI-95% upper	1.95	2.75	2.67	2.12	2.14	2.27	1.66	1.75
CV (%)	4.80	6.54	6.30	5.99	5.21	5.38	3.89	4.89
SWC (cm)	0.36	0.50	0.49	0.45	0.39	0.41	0.30	0.37
CI-95% lower	0.27	0.37	0.36	0.37	0.29	0.31	0.23	0.31
CI-95% upper	0.55	0.78	0.76	0.60	0.61	0.64	0.47	0.49

CI=95% confidence intervals; ES=Effect size; ICC=Intraclass correlation coefficient; CCC=Lin's coefficient of agreement; ρ =precision derived from CCC; C_b =Accuracy derived from CCC; SEM=Standard error of the measurement; CV=Coefficient of variation; SWC=Minimum worthwhile change.

The internal consistency of the ADR jumping is represented as well in Figure 2 where the existence of a linear dependence and the non-proportionality in the systematic error between attempts are appreciated, indicating a high internal consistency.

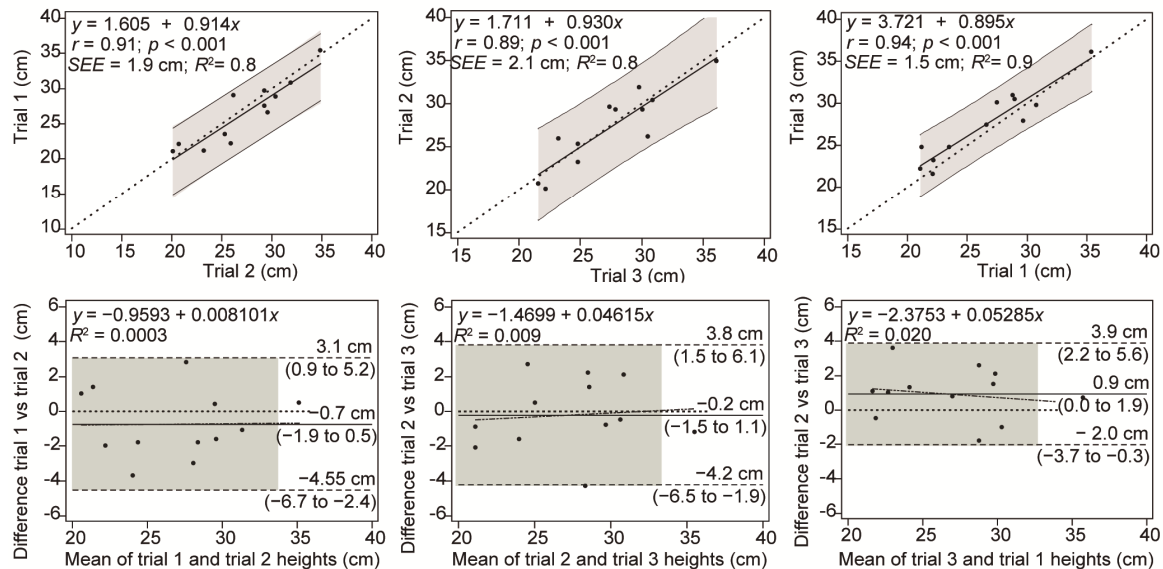


Figure 2. Within-session reliability (internal consistency) for consecutive trials of ADR jumping photocell. **UP:** Regression plots for consecutive pairs of jumps: Solid line: regression line; dotted line: line of perfect linearity; shadow area: confidence intervals for 95% of regression. **Down:** Bland-Altman plots for consecutive pairs of jumps between trials. Solid line: mean of the differences (systematic error); dashed line: upper and lower LoA (random error); dotted line: line of perfect agreement. dotted a dashed line: regression of the differences (proportional error); shadow area: confidence intervals for 95% of the LoAs and mean.

Discussion

The purpose of this paper was to analyze the existence of concordance when confronting the values of CMJ height from a jump mat (Chronojump) that has already been previously validated (criterion), against a new photocell ADR jumping photocell. In addition, it was intended to study the reliability, understood as internal consistency in the intra-session test-retest values of both instruments in a comparative way, to make scientific use of the ADR jumping photocell. From the knowledge of the authors, there are no studies in which the within-session reliability of ADR has been analyzed.

In terms of concordance between ADR jumping and Chronojump, the main findings observed show a high correlation between devices supported by a near-perfect Pearson's correlation coefficient ($r = 0.95$), and a mean difference (systematic error) of 0.81 cm, similar to those found in other studies in which photocells and jump mats are faced, however, the values find are slightly lower than those found for González-Conde et al. (2022) when compared both devices ($r = 0.98$) although the systematic error was very similar (0.84 cm). On the other hand, Patiño-Palma et al. (2022), found again similar correlation values ($r = 0.99$), differences in the mean of 0.96 cm and a very high concordance ($CCC = 0.89$), for the wheeler jump device, CCC allows making a deeper analysis of the concordance, in these study a very high concordance ($CCC = 0.94$) was found, larger than that found for the wheeler jump. In addition, these values also coincide with those found for photocells such as Optojump (Glatthorn et al., 2011; Rago et al., 2018) or Fitjump device (Yıldız & Fidan, 2020) when they are faced with force platforms (r ranging from 0.93 to 0.98 and systematic errors from 0.86 to 1.0 cm). Regarding the systematic error between devices, the bland Altman plot shows again a mean difference of 0.8 cm, with no proportionality observed. Despite this systematic error, the regression equation obtained ($H_{\text{Chrono}} = -0.475 \text{ cm} + 0.988H_{\text{ADR}}$) can partially correct it making the values obtained from ADR jumping and Chronojump interchangeable.

Regarding the consistency of the ADR jumping, the device is shown as a consistent instrument for consecutive attempts in the same session, with an ICC = 0.93 , and a CCC = 0.90 , obtaining very high precision values and almost perfect accuracy values for the CCC breakdown. The high values of error expressed as SEM (1.32 cm) stand out, however, are in line with the lack of precision observed in ρ and the values of CV = 4.9% . However, as the values of ICC are higher than 0.90 and the CV lower than 5% , the ADR jumper can be considered a reliable device in the within-session measurement (Hopkins, 2000). In addition, from the study of the linear regression, it can be deduced that there is a high degree of consistency with a slope always close to

unity, although the random errors reflected in SEE are somewhat high (2.5 -2.1 cm). on the other hand, the Bland Altman graphs also indicate a high degree of agreement between both trials since most of the points are between LoA. which is indicative of high consistency. Likewise, the degree of reliability shown by ADR is slightly higher than that shown by the jump platform, which also represents an indication of the consecutive reliability of the photocell, since Chronojump has already been considered reliable in consecutive attempts (ICC = 0.91, CCC = 0.87, CV = 5.9 %), SEM = 1.6 cm) by other studies (Pueo et al., 2018; Soler-López et al., 2022). If we compare the within-session reliability with that obtained by other photocells, we see that this does not differ too much from the observed data, thus, Rago et al. (2018) found values of (ICC = 0.87, CV = 4.2%) for the Optojump photocell, likewise. Patiño-Palma et al. (2022) for the Wheeler found very high values of reliability within-session (CV = 1.5%, SEM = 1.33). On the other hand, (González-Conde et al., 2022) found slightly lower values for the ADR jumper itself. However, the test-retest trials found are slightly lower, probably because the reliability analysis was carried out between sessions, which implies that other factors such as biological variability may affect the reliability of the test. In the same way, similar values were found reliable in the test-retest for Fitjump photocell (ICC = 0.97, CV = 2.3%) and Optojump (ICC = 0.98, CV = 2.7%, SEM = 2.4 CM), but again for between sessions reliability in both studies (Glatthorn et al., 2011).

In terms of sensitivity, ADR jumping shows higher values (SWC=0.37 cm) than Chronojump (SWC = 0.45), in any case, in both devices the SWC is lower than SEM, that is, the SWC could be covered by the noise of the instrument, which could become a problem in those situations in which detecting small changes in the CMJ is necessary.

Conclusions

This study demonstrates that the ADR jumping photocell is a valid instrument when compared to the Chronojump jump mat in the measurement of vertical height in CMJ, given the high concordance values found between both instruments. However, a systematic error of 0.8 cm is observed, therefore, the data from the ADR photocell and the Chronojump mat will only be interchangeable if the correction equation ($H_{\text{Chronojump}} = 0.988H_{\text{ADR}} - 0.475$ cm) is applied. Furthermore. ADR jumping shows high internal consistency values, therefore, can be considered a reliable device for the within-session test-retest in the measurement of CMJ in highly trained female athletes. Thus, ADR jumping can be considered an economic, portable, easy-to-use, and ecological option for the estimation of CMJ by coaches and physical activity specialists in order to monitor progress, set goals, and design training programs.

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Conflicts of interest

The authors have no conflicts of interest to declare.

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