EVALUATION OF RELIABILITY AND CONCURRENT VALIDITY OF INEXPENSIVE AND EXPENSIVE SYSTEMS USED FOR RECORDING MAXIMUM VERTICAL JUMP PERFORMANCE

Kajetan Slomka[1], Tomasz Skowronek[1], Marian Rzepko[2], Henryk Król[1],

Bogdan Bacik[1],Grzeogorz Sobota[1],Grzegorz Juras[1]
Academy of Physical Education in Katowice, Poland[1]
University of Rzeszów, Poland[2]

The reliability and validity of two alternative systems used for jumping performance measurement was evaluated. Two groups of subjects consisted of 15 male adults and the 16 female volleyball players. We used three different systems of data collection: Optojump Next (optoelectric) referred as the inexpensive system, BTS Smart-E (motion capture) as the expensive system. Concurrent validity of these systems was checked with the use of standard force platform. All systems were used to estimate the height of vertical jumps. Both systems showed highly reliability with the ICCs=0.98 for Optojump and 0.90 for BTS Smart. Their concurrent validity with the force platform data was also very high r=0.99 and r=0.97 respectively. Comparison of these two systems demonstrated distinct differences between the two systems: Optojump system is more suitable for quick and reliable sports testing.

KEYWORDS: counter movement jump, reliability, sports performance, optoelectric, motion capture

INTRODUCTION: Growing demands of sports professionals for a quick, valid and reliable estimates of performance induced development of alternative, easy to use methods of vertical jump height measurements. To meet the demands, simple devices like Vertec (Sports Imports, Hilliard, OH 43026) and different kinds of contact matts, which show high reliability and validity with more sophisticated devices have been developed (Leard et al., 2007). Currently, sports professionals face the difficulty in choosing an appropriate device, testing protocol and data processing procedure from many of those. Another problem might arise when dealing with different groups of subjects, for instance young, elderly, inexperienced and experienced sportsman. Literature review generally suggests that although there are a number of studies that explored various properties of the devices that can be used to measure the jumping performance, there is an apparent lack of their comprehensive evaluations and comparisons over a wide range of subject group.
Therefore, the aim of the present study is to evaluate two novel and relatively simple systems that allow testing the maximum jump height. Specifically, we evaluated the Optojump Next and BTS Smart-E systems through their reliability and concurrent validity as compared to the standard force platform data. The results are expected to reveal whether the evaluated systems (as well as other systems based on recording the flight time) can be used in routine testing of jumping performance in various athletic, recreational and other populations.

METHODS: We used three different systems of data collection. The systems were: Optojump Next (optoelectric), BTS Smart-E (motion capture), as well as the standard force plate. All systems were used to estimate the height of vertical jumps performed by the subjects. The study was divided into two experiments. Such necessity arose when we tried to use the motion analysis system in parallel with the Optojump Next system.
Two groups of subjects were tested. The first group consisted of 15 male adults voluntarily agreed to participate in the first experiment. These subjects were recruited from university students of the physical education course. Their average age, body mass and height were 21.3 ± 1.7 years, 73.8 ± 7.7 kg and 177.5 ± 1.5 cm respectively (mean ± SD). The second group of subjects consisted of sixteen female athletes recruited from an athletic school. Their average

age, body mass and height were 17.2 ± 0.9 years, 68.6 ± 8.4 kg and 181.3 ± 9.2 cm, respectively (mean ± SD). They were volleyball players at the level of first league competition. All subjects did not report any muscle or skeletal disorders. Prior to the experiment, all the subjects signed an informed consent. The study was approved by the Institutional Review Board of the Academy. In the first experiment, subjects' jumping performance was tested simultaneously by the Optojump Next system (Microgate, Italy) and a force platform (Kistler, AGWinterthur, Schweiz, Model 9281C). The Optojump bars were placed 1 m apart parallel to each other and where the ground surface was the surface of the force platform, thus allowing for the concurrent registration of the subjects' performance with both devices. Subjects' task was to perform a squat jump (SJ) with their knee joint bent approximately 100 degrees. The task was repeated 5 times with a rest interval between them of 10 s. Thereafter, subjects performed 5 consecutive counter movement jumps (CMJ) with the same break between jumps. All jumps were performed with no arm swing.

In the second experiment we have also used the force platform (Kistler, AGWinterthur, Schweiz, Model 9281C). The measurement was conducted simultaneously with motion capture system, BTS Smart-E (BTS Bioengeneering, Italy). During each series of jumps, the subjects were holding their hands on their hips. Both systems were registering performance concurrently. The Optojump Next system employs calculation algorithms to estimate the jump height that is based on main measurement parameters which is the time of flight (T_f). The use of force platforms gives more ways to calculate jumping performance. Similarly to Optojump system, it is possible to use time of flight in calculations ($H_{Tflight}$). Another way to calculate the jump height is to use maximal velocity at the take-off in order to estimate the height of the jump (H_{vel}). Finally, the third method, commonly used for vertical jump height calculations, is based on the trajectory of the center of mass (COM) (H_{traj}). These three methods are commonly used with force platform software.

Standard descriptive statistics were conducted. The Kolmogorov-Smirnov test revealed deviations from normality in none of the tested variables (all $p > 0.05$), which allowed use of parametric statistics. Correlation analysis was used to show the concurrent validity of the Optojump next system and force platform. In order to show possible differences in the results obtained from different devices one-way ANOVA was used, with Tukey HSD *post-hoc* comparisons when needed. The alpha level was set at $p<0.05$.The reliability of conduct measurements was estimated by the use of intraclass correlation coefficients (ICCs) (2,1) described by Shrout and Fleiss (1979) with 95% confidence intervals (CI).

RESULTS: The results of ICC show that both methods were reliable with a low number of repetitions needed to obtain very good reliability (Table 1). Interestingly, we have observed differences in the reliability coefficients of the height of jump measurements when we used different algorithm to process the data from the force platform, again these differences were very small, however, noticeable. We have observed that the highest values of reliability were obtained when the algorithm of time of flight was used (SEM was 0.45 cm in the case of CMJ and 1.01 in case of SJ). Similar results were obtained with the Optojump system indicating its high reliability of measurement.

Table 1. Reliability of counter movement jump (CMJ) and squat jump (SJ) heights estimated with the use of different methods.

Device	Test	ICC(2.1)	SEM (cm)	95% CI	ICC 95% CI	CV (%)
FP_H_{vel}	CMJ	0.88	1.11	36.84-41.20	0.782-0.946	0.17
FP_H_{traj}	CMJ	0.86	1.17	39.14-43.72	0.758-0.939	0.16
FP_$H_{Tflight}$	CMJ	0.98	0.45	40.21-41.97	0.961-0.991	0.17
Optojump	CMJ	0.98	0.48	35.11-36.97	0.958-0.991	0.20

FP_H_{vel}	SJ	0.77	1.56	30.14-36.24	0.615-0.894	0.20
FP_H_{traj}	SJ	0.80	1.31	32.89-38.03	0.632-0.910	0.17
FP_$H_{Tflight}$	SJ	0.88	1.01	32.68-36.65	0.735-0.951	0.18
Optojump	SJ	0.89	1.00	27.90-31.82	0.744-0.955	0.21

*Note:*FP = force plate, ICC = intra class correlation coefficients, SEM = standard error of measurement, CV = coefficient of variance

The results of ICC for BTS-Smart show again a very high reliability of measurements and are close to the ICC's obtained in the first experiment (Table 2).

Table 2. Reliability of counter movement jump (CMJ) height estimated with the use of force platform and motion capture systems (BTS).

Device	Test	ICC(2,1)	SEM	95% CI	ICC 95% CI	CV (%)
FP_H_{vel}	CMJ	0.91	0.45	29.06-30.81	0.840-0.966	0.11
FP_H_{traj}	CMJ	0.91	0.45	31.39-33.16	0.819-0.961	0.10
FP_$H_{Tflight}$	CMJ	0.92	0.44	30.20-31.94	0.825-0.963	0.10
BTS Smart	CMJ	0.90	0.50	26.43-28.40	0.808-0.963	0.13

Note: FP = force plate, BTS – motion capture system BTS Smart, ICC = intra class correlation coefficients, SEM = standard error of measurement, CV = coefficient of variance

Finally, in order to show the high concurrent validity of results obtained from the force platform and Optojump system, as well as the motion capture system BTS Smart, Pearson's correlation analysis was conducted (Table 3). The results show almost linear dependencies of these results and the strongest in case of algorithms using time of flight as the base variable in calculations.

Table 3. Correlation coefficients between Optojump Next (OJ) and BTS Smart (BTS) vs. Frorce Platform (FP) counter movement jump and squat jump heights calculated with the use of different algorithms.

	OJ_H_CMJ	OJ_H_SJ	BTS_CMJ
FP_H_{vel}	0.92	0.95	0.96
FP_H_{traj}	0.91	0.95	0.94
FP_$H_{Tflight}$	0.99	0.99	0.97

Note: CMJ = counter movement jump, SJ = squat jump

DISCUSSION: The main aim of the study was to verify the reliability of two measurement systems used for vertical jump performance and their concurrent validity with force platform data, considered to be the golden standard. One of these methods (i.e. Optojump Next) is a relatively inexpensive solution for jumping performance evaluation while BTS-Smart might be considered an expensive one. Each of the examined methods presented excellent reliability. They also presented very high concurrent validity with the force platform data. Depending on what device practitioners or researchers decide to use they will face different challenges. Methods like force platforms or motion capture systems are usually costly and demand trained individuals to use them. Another thing in the case of motion capture systems is time consuming procedures preparing the subject for the measurement. For these reasons they are not available for sports professionals in the regular training sessions. This is possible with the use of

Optojump system, which is very intuitive and does not need special instalment for its use. It is also portable system available to use in almost every training setting. The results of this study are in accordance with previous studies examining the reliability and validity of Optojump (Casartelli, Müller, & Maffiuletti, 2010; Glatthorn et al., 2011). In these studies, however, the authors did not present different algorithms used to calculate the jump heights from the force platform data. Considering the high reliability of these results, one can only assume that these algorithms are based on the time of flight. In our study, the highest ICCs were obtained from the time of flight algorithms. The highest concurrent validity of the results was also obtained with the use of the algorithms using time of flight to estimate the height of the jump. Therefore, we wanted to point out that researchers should be aware of differences coming from the use of different calculation algorithms or devices. The statistically significant differences between the force platform data and Optojump as well as BTS-Smart leads to another important observation, that with Optojump system or BTS-Smart system the results of vertical jump have tended to be underestimated. This can be explained by the way the subjects' performance is registered and the construction of these devices. The researcher has to be aware of these possible alterations to the final result and has to carefully control the execution of the task. This can be easily avoided when using different calculation algorithms with a force platform (e.g. algorithms using the initial velocity of the subject). It is also harder to cheat the motion capture system, and when the placement of the markers is appropriate (i.e. according to the acknowledged standards) it usually solves the problem. We have noticed that trials with SJ have produced lower indices reliability (in ICC) in comparison to CMJ (*Optojump test*). The movement structure of SJ is not very natural for human and might produce some difficulties in proper execution, thus generating more variability. Also, in case of SJ, Optojump shows similar or slightly more reliable results to force platform data. Although these differences are very small they are noticeable and proves that the Optojump system is a very good alternative to force plate or motion capture measurements. Both, reliability and concurrent validity of these methods are excellent but BTS-Smart stands as a research-grade device with much more flexibility of its use in a laboratory setting, giving the opportunity to measure much more aspects of movement behavior than just jumping.

CONCLUSIONS: Both examined systems give reliable and valid results, however sport professionals and researchers should be aware of possible differences coming from usage of different systems estimating vertical jump performance. Optojump system offers excellent reliability of measurement together with relatively low cost of purchase and portability. Researchers should very precisely control the testing procedure in order to avoid altering results in jumping performance.

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