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Original Article

RELIABILITY OF THE HIGH-SPEED CAMERA-BASED SYSTEM (HSC-KINOVEA) FOR LOWER-LIMB EXPLOSIVE STRENGTH ENDURANCE ASSESSMENT IN ATHLETES

CONFIABILIDADE DO SISTEMA DE CÂMERA DE ALTA VELOCIDADE (CAV-KINOVEA) PARA AVALIAÇÃO DA RESISTÊNCIA DE FORÇA EXPLOSIVA DE MEMBROS INFERIORES EM ATLETAS

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RESUMO
O presente estudo verificou a confiabilidade do sistema baseado em câmeras de alta velocidade (CAV-Kinovea) na avaliação da resistência de força explosiva de membros inferiores em atletas. Onze atletas masculinos de voleibol (21.8 ± 2.9 anos de idade; 186.3 ± 6.2 cm and 82.3 ± 11.0 kg) participaram do teste de saltos verticais de contexto intermitente em dois dias. O teste foi filmado e posteriormente analisado no software Kinovea 0.8.15 para obter as variáveis de potência pico e média. Para determinar a confiabilidade, utilizou-se o coeficiente de correlação intraclasse, o erro típico de medidas e os gráficos de Bland-Altman. O método apresentou valores satisfatórios para as correlações inter e intra-classe (>0,88). Os valores do erro típico de medida apresentados na análise interavaliadores foram 0,95 $W.kg^{-1}$ e 0,59 $W.kg^{-1}$ para potência pico e média, respectivamente. Nas análises intra-avaliação, os valores do erro típico de medida foram 7,02 $W.kg^{-1}$ e 5,66 $W.kg^{-1}$ (teste-reteste) e 1,59 $W.kg^{-1}$ e 0,24 $W.kg^{-1}$ (duplicados de vídeos) para potência pico e média, respectivamente. O sistema CAV-Kinovea é confiável para avaliar as variáveis da resistência de força explosiva em atletas.
Palavras-chave: Esportes. Recursos visuais. Confiabilidade dos testes. Resistência física.

ABSTRACT
The present study verified the reliability of the high-speed camera-based system (HSC-Kinovea) in the lower-limb explosive strength endurance assessment in athletes. Eleven male volleyball players (21.8 ± 2.9 years; 186.3 ± 6.2 cm and 82.3 ± 11.0 kg) participated in the intermittent vertical jumping test in two days. The test was filmed and later analyzed using Kinovea 0.8.15 software to obtain the mean and peak power variables. Regarding reliability, the intra-class correlation coefficient, the typical error of measurements, and Bland-Altman plots were used. The method presented satisfactory values for inter and intra-class correlations (> 0.88). The typical values error of measurement presented in the inter-rater analysis was 0.95 $W.kg^{-1}$ and 0.59 $W.kg^{-1}$ for the peak and the mean power, respectively. In the intra-assessment analyses, the typical measurement error values were 7.02 $W.kg^{-1}$ and 5.66 $W.kg^{-1}$ (test-retest) and 1.59 $W.kg^{-1}$ and 0.24 $W.kg^{-1}$ (duplicates videos) for peak and average power, respectively. The HSC-Kinovea system is reliable for assessing the variables of the explosive strength endurance in athletes.
Keywords: Sports. Visual resources. Reliability of the tests. Physical resistance.

Introduction

Team sports such as volleyball, handball, soccer, or basketball are composed of dynamic and explosive intermittent actions that combine cyclic and acyclic movements[1]. Among those, the vertical jump is considered one of the main actions for a successful competition[2-5] since the movement is performed several times during the match, making it crucial to maintain high levels of power (i.e., explosive strength endurance). Once the vertical jump and endurance of explosive strength during a match are crucial, different training and tests have been developed to improve and measure those characteristics[6,7].

The lower-limb explosive strength endurance can be assessed either by continuous or intermittent vertical jumps[8-10]. In a continuous test, the jumps are performed during 15, 30, and 60 seconds[8,10], whereas in an intermittent test, the jumps are performed during 60 seconds with 10-second intervals[9]. Variables that comprise the explosive strength endurance, such as mean power, jump height, and fatigue are obtained during the assessments[11,12] with force platforms, contact mats, and video analyses[8,9,11,13]. Nowadays, cameras are frequently used for the assessments, mainly because of the easy mobility, low cost, and long battery duration[14].

The high-speed camera-based (HSC-Kinovea) is an alternative measurement system for vertical jump that uses images through a camera with at least 240 frames per second[14]. In the study of Balsalobre-Fernández et al.[14] with physically active students, the validity, reliability, and validation of the method was performed, in which the flight time (FT) of a high velocity frame camera was recorded by the software Kinovea 0.8.15. The results presented high correlation intra-evaluators and high correlation with the infrared platform, method used for comparison[14]. According to previous findings, it is possible to speculate that the HSC-Kinovea system is useful in measuring the lower-limb explosive strength endurance in athletes for power (MP) and peak power (PP). However, a question needs to be clarified: Is the high reliability shown by Balsalobre-Fernández et al.[14] maintained in consecutive jumps?

Reliability, an evaluation method obtained using standard error and the intraclass correlation coefficient (ICC), is crucial to ensure replication in athletes[15]. Thus, the study aims to evaluate the KSC-Kinovea system's reliability for PP and MP in consecutive vertical jumps. The instrument's reliability is vital because it might help sports professionals evaluate lower-limb explosive strength endurance in athletes during the season.

Methods

Participants

Eleven male volleyball players (21.8 ± 2.9 years; 186.3 ± 6.2 cm and 82.3 ± 11.0 kg) participated in the study with more than four years of training and competitions in the modality. The athletes play for a Brazilian National League team, and were selected for convenience. As inclusion criteria, the participants should present no muscular or joint injuries or any problem that could impair any assessment. All participants who volunteered, a total of 11, met the inclusion criteria and signed the informed consent form, and the Ethics Committee approved the study of the Federal University of Pernambuco under number 1.575.390/2016. This study was performed in agreement with the Declaration of Helsinki for Human Research.

Procedures

Initially, the participants were measured for height and weight. Intermittent vertical jumps assessed the lower-limb explosive strength endurance. A familiarization was carried out right before the assessments, once the participants were already familiarized with vertical jumps. Also, the participants were asked to avoid performing any exercise 24 hours before the assessments, abstain from smoking and any ergogenic, and maintain regular eating habits and sleeping hours.

The intermittent vertical jumps were performed on two different days, at the same local (volleyball court) and time (4 p.m.), separated by 72 hours. The study’s design was adopted to permit the assessment of inter- and intra-evaluator.

Two evaluators, “A” and “B”, were recruited to the intra- and inter-evaluator reliability assessments without any experience in the analysis. The evaluators identified the FT and determined the MP and PP. The reliability inter-evaluator was performed comparing the videos from evaluator A and B of moment one. The videos of moment one, filmed by evaluator B, were duplicated. The reliability intra evaluator was performed in two ways: i) comparing the videos form evaluator A of moments one and two (test and retest) and ii)

Comparing the duplicates videos form evaluator B of the moment one, that is, the first testing session, with an interval of 15 days.

Explosive strength endurance of lowers limbs

Initially, the participants underwent a 10-minute warm-up composed of a 5-minute submaximal effort in a treadmill, lower-limb stretching, and ten submaximal vertical jumps.

The protocol of intermittent vertical jumps (IVJ_{60}) used in this study was proposed by Hespanhol et al.[10]. It is composed of four sets of 15-second with a 10-second interval between the sets. The participants were asked to perform the highest possible vertical jump with hands on the hip to avoid any additional boost.

The data of the IVJ_{60} were registered according to Balsalobre-Fernández et al.[14], using the camera Casio Exilim FH-25 (Casio Computer Co., Ltd., Tokyo, Japan), 448 x 336 pixels and 240 fps. The camera was positioned near to the ground (15cm) and approximately 150 cm from the athlete. The videos were analyzed by the software Kinovea 0.8.15 for Windows (Bordeaux, France), which measured FT in milliseconds. Kinovea is a free software under the GPL v2 license" (link https://www.kinovea.org/). The FT was estimated by the frame to frame analysis in each vertical jump using the software Kinovea 0.8.15. The time between the last contact frame in the contact of the ground again was considered the FT.

The variables MP and PP were used to analyze the reliability. The MP was calculated using the equation (1) proposed by Bosco et al.[8], where n = number of vertical jumps during 15 seconds, g = 9.81 m.s-1 and FT_{60} = flight time during the 60 seconds of the test. The PP was measured by the equation (2), also proposed by Bosco et al.[8], which n = number of vertical jumps during 15 seconds, g = 9.81 m.s-1 and FT_{15} = flight time during the 60 seconds of the test.

$$PM = \frac{g^2 \times FT_{60} \times 60}{(4 \times n)(60 - FT_{60})} \tag{1}$$

$$PP = \frac{g^2 \times FT_{15} \times 15}{(4 \times n)(15 - FT_{15})} \tag{2}$$

Statistical analysis

The comparison of the measurements was made by the ICC, with a 95% confidence interval (CI). The ICC values were defined according to Fleiss[16] criteria: < 0.4 = low reliability; 0.4 to 0.75 = good reliability and > 0.75 = great reliability. The typical error of the measurement (TEM) was performed according to Hopkins[17]. Also, biases and limits of agreement were analyzed using Bland Altman plots[18], and heteroscedasticity was analyzed using linear regression between the absolute values of differences and means, using $R^2 > 0.1$ as the presence criterion[19]. The TEM was determined by the formula TEM = SD/√2. The data were analyzed using the software IBM SPSS Statistics for Windows, version 21.0 (IBM Corp., Armonk, N.Y., USA) (https://www.karger.com/Article/Fulltext/381953). The statistical significance was set at 5%.

Results

The ICC indicated great reliability inter- and intra-evaluator (Table 1). The Bland-Altman plots showed degree of agreement between the evaluators for PP, BIAS = 0.89 ± 2.63 $W.kg^{-1}$, and MP, BIAS = 0.33 ± 1.64 $W.kg^{-1}$, (Figure 1). In the test and retest, the BIAS values for PP e MP were -2.44 ± 19.47 $W.kg^{-1}$ and -3.35 ± 15.70 $W.kg^{-1}$, respectively (Figure

2). Regarding the duplicated videos of the first testing session (moment 1) analyses, the BIAS values were - 0.19 ± 4.43 W.kg^{-1} and 0.10 ± 0.67 W.kg^{-1} for the PP and MP, respectively (Figure 3). The TEM values of the PP and MP in the inter- and intra-evaluators comparisons are reported in Table 1.

Table 1. Inter and intra reliability for peak power (PP) and mean power (MP) analyzed through the IVJ_{60}

Variables	Indicators			
	ICC	CI (95%)	*P*-value	TEM (W.kg^{-1})
Inter-evaluator				
PP	0.99	0.98/1.00	0.001	0.95
MP	0.99	0.99/1.00	0.001	0.59
Intra-evaluator				
Test and retest				
PP	0.86	0.47/0.96	0.002	7.02
MP	0.88	0.54/0.97	0.001	5.66
Duplicates videos				
PP	0.98	0.94/0.99	0.001	1.59
MP	1.00	1.00/1.00	0.001	0.24

Note: ICC = Intra-class correlation coefficient, CI = confidence interval, TEM = typical error of the measure
Source: Authors

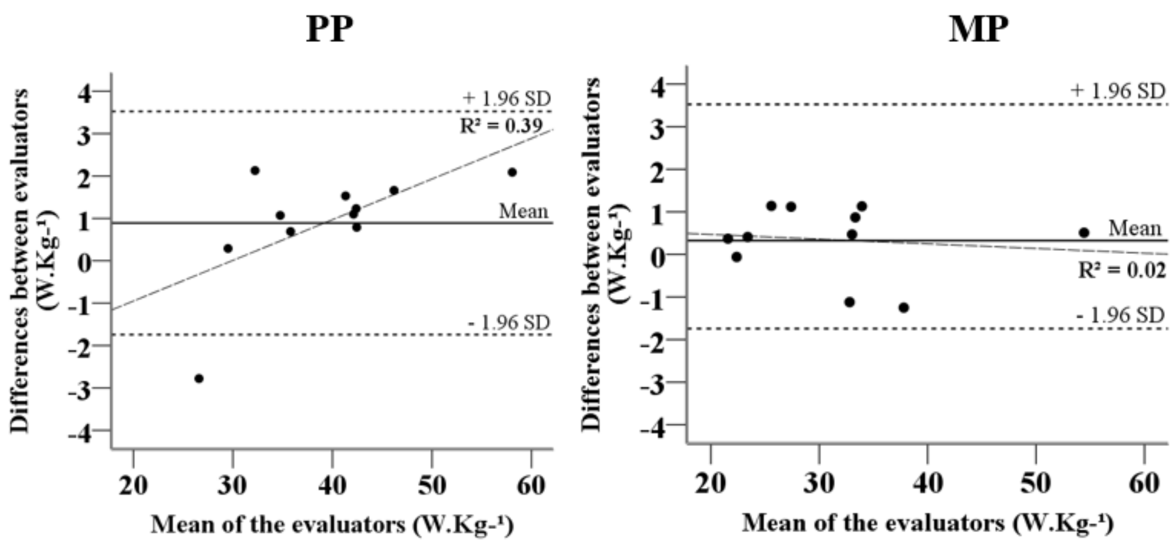

Figure 1. Bland-Altman showing the agreement of the video analyses for the evaluators “A” and “B” in the moment 1 for the peak power (PP) and mean power (MP).
Source: Authors

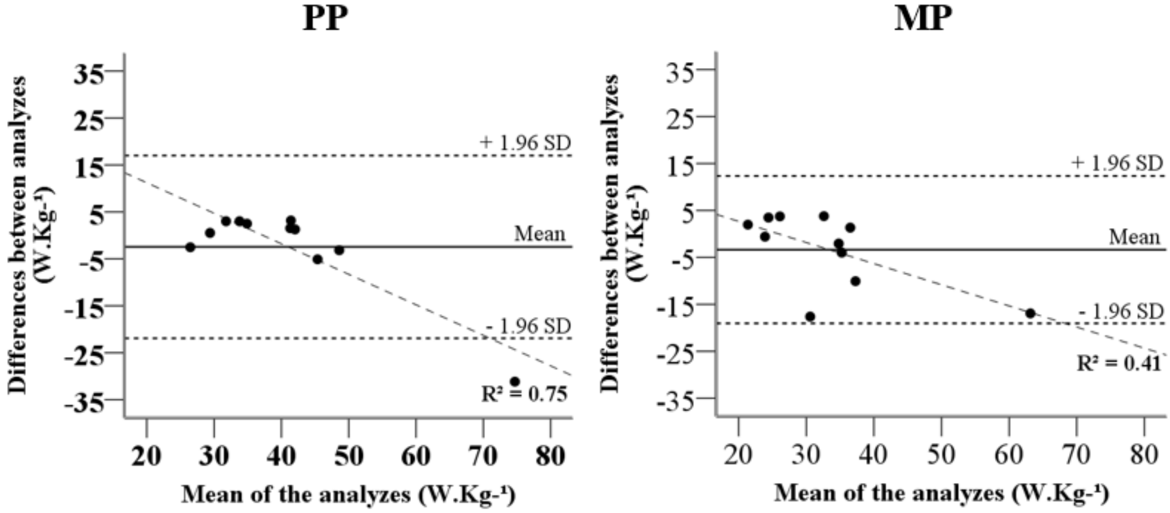

Figure 2. Bland-Altman showing the agreement of the video analyses for the test-retest of the evaluator "A" for the peak power (PP) and mean power (MP)
Source: Authors

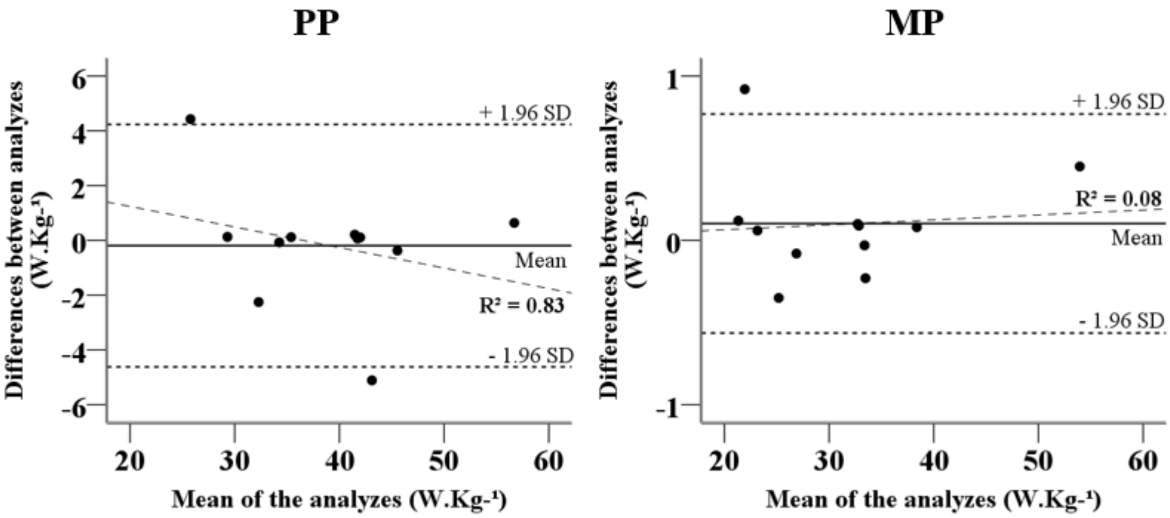

Figure 3. Bland-Altman showing the agreement of the duplicated video analyses for the evaluator "B" in the moment 1 and following 15-days for the peak power (PP) and mean power (MP)
Source: Authors

Discussion

The main objective of the present study was to analyze the inter- and intra-evaluator reliability of HSC-kinovea to assess the lower-limb explosive strength endurance in athletes. Following the ICC analyses, great concordances were observed for both inter- and intra-evaluator. The results indicated that the HSC-Kinovea system is reliable for measuring lower limb power endurance in male volleyball athletes. According to Atkinson & Nevill[19], inter- and intra-evaluator reliability is necessary to guarantee measurement quality and accuracy. The information provided by this experiment is relevant and permit the evaluator to observe the changes in the athletes' performance in a certain period, if any, or whether the measurement error causes the difference. Measurement error might be caused by any instrument failure or inadequate administration of the protocol[19].

In this sense, TEM is pointed out by Hopkins[17] as a precise method to verify the reliability, identifying athletes' changes in different outcomes. Besidess, according to the author, changes between the pre- and post-test should only be accepted if the value is superior to the TEM. In the present study, the TEM values of the inter-evaluator's reliability were 0.95 $W.kg^{-1}$ and 0.59 $W.kg^{-1}$ for PP and MP, respectively. Those results indicate the HSC-Kinovea is sensitive to small changes that might be found during the protocols in athletes. The TEM values of the test-retest intra-evaluator reliability were superior when compared to inter-evaluator reliability, 7.02 $W.kg^{-1}$, and 5.66 $W.kg^{-1}$ for PP and MP, respectively. According to Pyne, Trewin, and Hopkins[20], motivation and fatigue might influence the test performance, then, reliability. Atkinson and Nevill[19] indicated that TEM is originated from biological and technological sources, whereby the biological sources are related to variation in human physiology. Thus, The TEM values found in this study are considered acceptable.

Low scores of BIAS values, - 0.19 ± 4.43 $W.kg^{-1}$ and - 0.10 ± 0.67 $W.kg^{-1}$ (Figure 3) and TEM 1.59 $Kg.W^{-1}$ and 0.24 $W.kg^{-1}$ (Table 1) for PP and MP were found by the evaluator B during the duplicated video of first testing session analysis (moment 1). It might confirm that the values found in the TEM for test-retest reliability are due to biological variations. Also, a good agreement between both analyses evaluators and the small differences found in the values are considered the measurement error. This scenario guarantees the quality of the results, indicating that most of them are, in its majority, due to biological variations and not by any error during the measurement and video analyses. Contributing to the hypothesis, values similar to those of the present study for MP change, ~ 4.94 $W.kg^{-1}$, were found in the literature in young volleyball athletes after four weeks of training[13].

The HSC-Kinovea is reliable for analyzing FT in consecutive vertical jumps, adding new information to the previous study[14]. However, to the best of our knowledge, no study investigated the reliability of the HSC-Kinovea for lower-limb explosive strength endurance assessment. The HSC-Kinovea system is reliable for analyzing FT in vertical jumps[14]. However, it was not elucidated if the system could assess the lower-limb explosive strength endurance during consecutive vertical jumps. The present study results favor the device and system for short-duration tests (15 seconds)[8], and the intermittent tests (60 seconds or more) [10]. Thereby, PP is analyzed during the first 15 seconds and MP in the total time (60 seconds). The technical staff of each sport might determine the duration of the test based on the real matches. According to the results, the HSC-Kinovea is reliable to evaluate the heights of vertical jumps, when performed consecutively, and consequently capable of estimating the variables of the explosive strength endurance, adopting consecutive vertical jumps for 30 seconds, validated by Dal Pupo et al.[9].

Therefore, it is suggested that other studies should be conducted with this system, analyzing the results in different modalities and athletes, being considered only alterations above TEM. As a limitation of the analyzed system, the results are not available in the exact moment of the test. However, our study shows that the device is easy to handle, and within 30 seconds, it is possible to record the TF.

Conclusion

It is concluded that the high-speed camera-based system (HSC-Kinovea) is reliable in the lower-limb explosive strength endurance assessment in athletes. This physical capacity is essential to sports that require several jumps during a match, such as volleyball, handball, and basketball. Thereby, the HSC-Kinovea system might help coaches and sports professionals to control the lower-limb explosive strength enduranc and improve the training program. According to the TEM values in the inter-evaluator, < 2.0 $W.kg^{-1}$, it is verified that the method is sensitive to PM and PP alterations in athletes. Although the variables were estimated, the results make possible the use of HSC-Kinovea for analyses of lower-limb explosive strength endurance in athletes, especially for teams that do not have a financial contribution to acquire more sophisticated instruments. Moreover, it might be applied according to each sport's specificity, using long and short duration tests.

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