Reliability and Usefulness of Maximum Soccer-Specific Jump Test: a Valid and Cost-effective System to Measure on Soccer Field.

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Original Investigation

Running head: New jumping test in soccer and cost-effective instrument

Abstract

The aims of this study were (a) to assess intra-session reliability and usefulness of the soccer-specific maximum vertical jump (heading test, HT) and (b) to analyse the validity of the easy-to-use and cost-effective instrument (smartphone camera, MOB) compared with gold-standard instrument (3D motion capture system, MOCAP) to obtain the vertical jump performance during HT. Twelve semi-professional high-level and fifteen amateur soccer male players (23.9±3.6 years) performed three HT attempts, and kinematic data were recorded with MOB and MOCAP. Intra-class correlation coefficient (ICC) and coefficient of variation (CV) were used as measures of intra-session reliability. T-test with Cohen's effect size (ES), Pearson's product moment and Bland-Altman analysis were used to obtain MOB validity. Regarding intra-session reliability, the CV was 1.13%, and ICC was 0.98, considered *acceptable*. Respecting validity criteria did not reveal significant differences ($p<0.05$; effect size=0.06, considered *trivial*), "almost perfect" correlation (Pearson) ($r= 0.98$; $p < 0.05$), and strong agreement were obtained between MOB and MOCAP. This finding showed a test (HT) with a specific character, using cost-effective instrument and applicable to all soccer fields (adjusted to the standardized lines in the soccer field), all of them backed-up by reliability, usefulness and validity criteria.

Key words: testing, soccer, assessment, performance, jumping.

Introduction

The majority of the actions performed in a soccer match are of low-intensity such as walking and jogging, interspersing a high number of bouts high-intensity exercise (Iaia et al., 2009). In fact, high-intensity actions have increased in recent years during soccer matches, playing a decisive role in the competition (Barnes et al., 2014). In soccer, a jump means jumping header, a crucial motor skill related to soccer. In fact, during the South Africa World Cup the ~20% of the goals were scored by headers (Njororai, 2013).

Previous study reported 52±15 aerial heading during per match with different header purpose (pass, shot, interception, clearance), jump movement (standing, nº steps forward, sideways or backward), and jump type (1-foot, 2-foot parallel, 2-foot horizontal or sideways), which depend on contextual variables (e.g., position-specific needs) (Sarajärvi et al., 2020). Heading a ball is a complex skill requiring precise timing, coordination, and strength that may take place while running, standing, jumping forward or backward, or diving or when challenged by an opponent (Spiotta et al., 2012).

The player's vertical jump performance (height) seems to be a clear plus for better performance in heading (Marcolin et al., 2007; Paoli et al., 2012). The maximum effective heading elevation of the header related to the ball speed increments and to the correct ball angles (Marcolin et al., 2007). Therefore, the previous authors defined "elevation index" as the percent ratio between the jump elevation and the anthropometric height of each subject, and the authors concluded that the best heading players corresponding to best elevation indexes and best ball speed increments (Marcolin et al., 2007).

On the one hand, VJ tests were positively and strongly associated among each other, with the highest correlation coefficient values existing between the countermovement jump (CMJ) and VJ 1-leg ($r = 0.89$) (run-up with 1 leg take-off jump) and 2 leg ($r = 0.93$) tests in U-15, U-18 and adults soccer/basketball players (Rodríguez-Rosell et al., 2017). These high correlations imply that some of the simple vertical jump tests (i.e., no sport-specific skill involved) can be interchangeably used. Conversely, Requena et al (Requena et al., 2014) showed that soccer-specific VJ test with ball presence was either weakly or moderately related to traditional standing VJ tests when considering critical jump performance variables (e.g. take-off velocity).

The differences between these two aforementioned studies (Requena et al., 2014; Rodríguez-Rosell et al., 2017) could be due to differences in protocol criteria, skills involved and sample. Requena et al. (Requena et al., 2014) employed soccer-specific VJ in professionals soccer players involving a run-up phase and ball suspended as a target overhead of the soccer player that caused a parabolic trajectory. By contrast, Rodríguez-Rossel et al. (Rodríguez-Rosell et al., 2017) designed a specific protocol where non-professionals and young soccer players performed run-up phase and jump without ball presence that caused purely vertical displacement. In this sense, previous authors considered that this restriction allowed a good scientific evaluation of the skill, which is likely to introduce less variability than jumping utilizing real movement (heading jump is performed usually by parabolic trajectories). However, soccer-specific VJ with *versus* without ball overhead inclusion causes a completely different movement in some kinematic and kinetic variables (e.g., ball presence causes an alteration of the jumping strategy with an increase of 4.3% in vertical jump, shorter contact time and higher rate of force development compared to jump without ball presence) (Fílter et al., 2021). This finding, to a certain extent, questioned the use of traditional VJ (without ball presence and run-up phase) to know jumping ability in the soccer player.

Soccer-specific VJ with ball presence and run-up phase, in other words, the Heading Test (HT), can be measured with 3D motion capture system (MOCAP). However, a key drawback of this technology is the high cost. Taking as a basis the highlighted information, an easy-to-use and cost-effective instrument to assess HT is necessary for practitioners.

One of the easiest and cheapest ways to measure performance during a HT is by means of a smartphone camera. Balsalobre-Fernándezet al. (Balsalobre-Fernández et al., 2014) showed that CMJ height can be easily, accurately and reliably assessed using a mobile app (named: My Jump), but this can only be used to assess fully vertical displacement. We could not use time (s) as a unit of measure herein due to the fact that our design focused on a HT, where soccer players performed following a parabolic trajectory to reach the ball. For the sake of clarity, parabolic trajectories depend on, among others, take-off angle. In this line, two parabolic jumps with same flight time and different take-off angle could report different height jump.

The main aims of this study were (a) to assess intra-session reliability of the HT (soccer-specific maximum vertical jump), (b) to check the usefulness criteria, and (c) to analyze the validity of the smartphone camera with easy-to-use video software analysis (i.e., Kinovea 0.8.15 for Windows, https://www.kinovea.org/) to obtain the jump height (cm) during HT. It was hypothesized that (a) HT results will show high repeatability during the three proper attempts, (b) HT will achieve usefulness criteria, and (c) HT results using the camera of the smartphone (MOB) will be highly correlated with MOCAP set as the gold standard instrument.

Methods

Tester

The same tester developed this research. The tester was highly experienced (specific training and more than 5 years of experience) in the use of smartphone-Kinovea (MOB) for markerless movement analysis. The tester was also experienced with marker-based 3D motion capture system (MOCAP).

Participants

Twelve high-level (first three Spanish leagues) and fifteen amateur soccer players volunteered to participate in the study. Their (mean ± SD) age, height and body mass were 23.9 ± 3.6 years, 175.1 ± 5.2 cm and 71.7 ± 3.6 kg, respectively. All subjects had more than 12 years of experience in soccer and had five training sessions and one day of competition per week. In order to be included in the study, subjects had to: 1. ensure regular participation in all the training sessions, 2. have competed regularly during the previous competitive season and 3. possess medical clearance. Goalkeepers were excluded from the investigation. `All subjects were informed of the risks and benefits of the procedure and signed an informed consent for test participation. The study methodology was approved by the local Ethics Committee, and was carried out in accordance with the Declaration of Helsinki.

Data collection protocol

This study was designed to assess the absolute and relative intra-session reliability, usefulness of HT, and the validity (correlation and agreement) of the data obtained from the MOB to the MOCAP. Participants attended the Sport Science Laboratory on two occasions (familiarization and data collection) to participate in a testing session, and tests were performed under similar environmental conditions (21-22 ºC, and 35% of relative humidity). The test session consisted of a warm-up that included a series of jogging, dynamic range of movement activities and sub-maximal HT before completing the HT. The protocol of the HT adopted the same characteristics as the study conducted by previous study (Requena et al., 2014) (fig. 1). High-level soccer players (professionals and semi-professionals) performed three correct trials (36 jumps were analyzed for HT validity, reliability and usefulness analysis) and 5 trials were collected in amateur soccer players (75 jumps for MOB validity analysis), with a complete recovery time (2 minutes) to avoid a fatigued state. Before performing the test, a ball suspended in the air was adjusted for each subject (1-m overhead with the aim to create false expectations to make contact). The movement technique was unrestricted, except the run-up distance that was set up using the ball as a point of reference.

[Figure 1 near here]

Heading test (HT)

The illustration of the HT is shown in figure 2, 3a and 3b (Requena et al., 2014). A soccer ball was positioned in the middle of the testing area, 1-m above the subject's standing height (fig. 1). The height of the ball was chosen in order to extract a maximal effort from the players and to avoid contact with the ball during jumping. All trials for the HT began from the area perimeter and were performed using a 5.5-m run-up at a self-selected speed and number of strides (fig. 3a). The run-up distance was the only limiting or restricting variable. The instructions were: 1. Begin the run-up on testing area (5.5-m radius from the ball) and 2. Perform a maximal run-up jump with the aim of heading the ball from maximum perceived distance using a technique that mimics actual play.

[Figure 2 near here]

[Figure 3a near here]

[Figure 3b near here]

Equipment

The height of the soccer-specific VJ was determined using the MOCAP (Qualisys, AB, Gothenburg, Sweden) at a sampling rate of 200 Hz was used and MOB (Lenovo, Beijing, China) at a sampling rate of 30 fps (1920 x 1080 pixel). The Smartphone camera recordings were subsequently analyzed using the open-license analysis video software (Kinovea 0.8.15 for Windows). A similar device was used by other authors (Balsalobre-Fernández et al., 2015) to measure vertical jump performance through the flight time (s) variable. An instrument to suspend the ball and adjust the height above the soccer player head was designed and simulated in the laboratory (fig. 2).

Data analyses

A total of 36 jumps were analyzed for the calculation of reliability and usefulness, and 111 jumps were used for the calculation of validity of the MOB divided into two groups (high-experience = 36; amateur = 75). MOCAP and MOB use images, based on a proper previous calibration, and frame-by-frame analysis in order to obtain the maximum jump height recorded. Kinovea can complete the analysis without the use of physical sensors or by means reflective markers and it is uncomplicated to use. The overview function is a summary image of the video (fig. 4). It creates a composite picture where you can see the motion at a glance by sample images from the video at regular intervals. Accordingly, a previous study verified Kinovea has the potential to be used as a motion capture-analysis tool and can be used in this research field (Grigg et al., 2018). To record more accurate movement, the subjects wore a reflective marker on the hip (trochanter marker) as a point of reference to calculate the height achieved with Kinovea (fig. 4). Regarding the space calibration, reference distance was obtained between trochanter maker and knee marker as constant distance. The camera of MOB was placed in front of the goal post, specifically on the small area line (5.5 m from the post and ~ 5 m from the ball), and was fixed with a tripod at a height of 1-m (fig. 3b). Some guidelines (from Kinovea reference guide) to reduce accuracy errors during MOB recording were followed: 1. lines measured must be on the same image plane, 2. this plane must be perpendicular to the camera axis, 3. the line segments (reference and measured) should be close to the center, 4. measured segments should be close to a reference segment, and 5. if segments are on different images of the video, the video must be fixed relative to its environment (no pan, no zoom). For the MOCAP analysis of the marker trajectories, with 2 markers (trochanter and knee) were attached to the participants' body (fig. 5). The distance from the lateral knee to the great trochanter, as well as the displacement of the latter, were calculated using the software Visual3D (C-Motion, Bethesda, Maryland).

[Figure 4 near here]

[Figure 5 near here]

Statistical Analysis

The statistical analysis was completed using the SPSS 21.0 (Version 21, SPSS Inc., Chicago, IL, USA). Descriptive statistics are expressed as mean ± standard deviations (SD), in addition to 95% confidence limits (95% CL). The normality of the data distribution was checked using the Shapiro-Wilk test.

Reliability and usefulness study statistical analysis

A total of 36 jumps performed by high-level soccer players were analyzed. A one-way repeated measures Analysis of Variance (ANOVA) was used to calculate the differences between attempts. Absolute reliability is the degree to which repeated measurements vary for individuals (repeatability) and the spreadsheet of Hopkins was used to determine the typical error (TE) (s), expressed as a CV%. A CV of less than 5% was set as the criterion for reliability (W. G. Hopkins et al., 2001). For the relative reliability analysis, intra-class correlation coefficients (ICC [two-way mixed single measures]) were used. An ICC equal to or above 0.7 was considered acceptable (Baumgartner & Chung, 2001).

The usefulness of the test was determined by comparing the TE to the smallest worthwhile change (SWC) for each test (height [cm]) (W. Hopkins, 2004). The SWC was determined by multiplying the between-subject SD by either 0.2 ($SWC_{0.2}$) (W. Hopkins, 2004), which is the typical small effect. If the TE was below the SWC, the test was rated as "good"; if the TE was similar to the SWC, the test was rated as "OK"; and if the TE was higher than the SWC, the test was rated as "marginal".

Validity study statistical analysis

Validity is also extremely important as it deals with the fundamental question of whether the test is really assessing what it purports to measure. A total of 111 jumps were analyzed, 36 jumps by high-level players and 75 by amateurs. The criterion related validity has been established by assessing the relationship between MOB data and MOCAP data using a Pearson product moment correlation coefficient with 95% CI, which was classified according to the criteria defined by Hopkins et al. (Hopkins et al., 2009). Additionally, paired samples t-test with effect size (ES) (Hopkins et al., 2009) and Bland-Altman plots (Bland & Altman, 1986) were calculated to compare two measurement techniques (MOB *vs* MOCAP) to obtain the agreement between both instruments. The level of significance was set at $p < 0.05$.

Results

Reliability and usefulness study results

All the collected outcomes presented a normal distribution ($p > 0.05$). Descriptive data of the different attempts and the TE values expressed as %CV calculated from three consecutive attempts are presented in Table 1. The CV was less than 5%, specifically 1.13%, and ICC was 0.98, considered *acceptable*. For HT test, the TE was either below to the $SWC_{0.2}$ (table 1).

Validity study results

Regarding the validity criterion, “almost perfect” correlation (Pearson) was reported for professionals and amateur, and strong agreement (Bland-Altman) (table 2) were found between data obtained with the MOB and the MOCAP instruments for both high-level and amateur players which showed no heteroscedasticity in the distribution of the difference between devices as revealed by Bland-Altman plots (fig. 6). Bland and Altman’s plot depicting limits of agreement for HT height between the MOCAP and MOB show that the majority of data points are within the 95% CI’s (fig. 6). Further analysis of the Bland-Altman plots in players revealed very low R^2 values in high-level and amateur ($R^2 \leq 0.0008$ and $R^2 \leq 0.0029$, respectively), meaning outcomes estimated from MOB had no predisposition to overestimate or underestimate jump performance. T-test did not reveal significant differences ($p > 0.05$; ES from 0.06 to 0.09, considered *trivial*).

[Table 1 near here]

[Table 2 near here]

[Figure 6 near here]

Discussion and implications

The results of the study confirmed the hypothesis, showing that (a) HT performance assessment maintained proper repeatability (intra-session reliability), (b) HT achieved “good” usefulness, and (c) the assessment of HT using MOB was accurate due to high correlation and agreement with the MOCAP.

Reliability and usefulness criteria

The HT measured obtained a proper repeatability (table 1). The data showed a %CV less than 5% (table 1), which confirms the HT repeatability. The %CV was similar to other jump tests (~2.0%) that were determined to be reliable (W. G. Hopkins et al., 2001). Additionally, the present study used a highly experienced sample, which according to previous mentioned authors, likely contributed to achieve the reliability criteria. A study that analyzed the reliability of specific vertical jumps test in volleyball players reported similar results to those of the present study (CV = 2.1% and 2.8%) (Sattler et al., 2012).

The CMJ and SJ tests have been used extensively, and there are several studies that have checked their reliability (reproducibility and repeatability) (Arteaga et al., 2000; Goran et al., 2004; Slinde et al., 2008). However, the CMJ or SJ tests are standard rather than sport-specific jumping tests. In fact, "weak" and "moderate" relationships (Requena et al., 2014) were found between traditional vertical jump and HT as a result of the kinematic and kinetic differences caused by the ball presence (Fílter et al., 2021). This study aims to show a soccer-specific test (HT) under contextualized approach (close to competition pattern movement), with players performing movement that mimics an actual match-play scenario, achieving the reliability criteria. A previous study confirmed the reliability of soccer-specific VJ test (Requena et al., 2014), and the authors obtained acceptable repeatability (CV = 2.5%), similar results were found in the present study (CV = 1.13%). In spite of the reliability of parabolic movements have been questioned (Rodríguez-Rosell et al., 2017), the reliability criteria have been achieved in this study. These data suggest that, although there is an extend inter-subject variability in some kinetic and kinematic variables during the HT (Fílter et al., 2021), high experienced soccer players usually repeat the same movement pattern when they jump to the ball, achieving high intra-session reliability. The current study highlights the possibility of including a simple and reliable HT in the specific strength-power assessment undertaken by strength and conditioning professionals.

In addition, the level of the test usefulness was considered. As can be seen in Table 1, the TE for the HT was below the $SWC_{0.2}$, which provides a usefulness rating of "good". This is pertinent, as within the context of this study, the results did indicate that the HT was a useable assessment of jump ability in soccer players. A limitation of the HT is that it may not be applicable for low experienced soccer players (i.e., young players) who maybe increase the test variability. This variability, in amateur players, could be mitigated by increasing the number of restrictions/limitations (e.g., steps during run-up approach, type of jump [two-leg jump]).

Validity criteria

"Almost perfect" relationship obtained with Pearson correlation coefficient and not significant differences ($p < 0.05$; ES = 0.06, considered *trivial*) between MOB and MOCAP data confirmed the validity and accuracy of the MOB to measure performance during HT (table 2) for both high-level and amateur soccer players. This means that validity data are not modified if the sample is changed. In addition, Bland-Altman plot, which compared two measurements (MOB versus MOCAP) of the same variable (height), confirmed the strong agreement. These findings suggest that although analyzing the data obtained with the smartphone camera (MOB) is time consuming, an easy-to-use app such as the one used by Balsalobre-Fernández et al. (Balsalobre-Fernández et al., 2014) could be designed to measure performance during HT, which mimics the actual game action, with no relationship with traditional standardized vertical jump (Requena et al., 2014). In fact, the ball-presence during run-up vertical jump causes a completely different jump pattern movement (i.e., kinematic and kinetic differences)(Fílter et al., 2021). Thus, when compared to MOCAP, the MOB can be considered as a valid and cost-effective alternative to practitioners who are seeking to assess HT.

The present work was not the first to verify the validity of the smartphone camera comparing it with MOCAP. Another work has already confirmed it (Grigg et al., 2018; Nor Adnan et al., 2018) and showed the capability of Kinovea to be used as a motion capture-analysis instrument. Some authors revealed strong agreement between 2D (cameras with sampling rate of 60 frames per second and Kinovea software) and 3D (motion-capture system gold standard) measurement techniques in the sagittal plane at the hip (r = 0.93) and knee (r = 0.86) (Schurr et al., 2017). The authors mentioned suggested that future studies should evaluate the use of mobile technology in the quantification of lower extremity kinematics during functional tasks, in an effort to move towards an even more expedient and efficient method of assessment. In accordance with this suggestion, the present study confirmed that MOB, as a motion captures system, is valid and reliable under specific conditions (fig. 3a and 3b). It could be concluded that this study has contributed significant and new knowledge about parabolic movement (HT) analysis using MOB with an image processing system (i.e., Kinovea). This study not only provides validity criteria for a cost-effective instrument (MOB), but also shows the reliability and usefulness of soccer-specific test (HT) that changes in this test could be directly related to changes in soccer-specific actions during the match (i.e., heading a ball).

Limitation

We only analyze a specific device using a low sample of high-level players. Checking the validity of other devices that are on the market to measure HT would bring really implementable knowledge to soccer context. A larger sample of high-level players with different characteristics (i.e., different playing positions [headers vs non-headers], different sexes) could provide more information on the HT reliability to apply in another type of population (e.g., female player, top-headers amateur players).

Conclusion

The current study confirmed the hypothesis: despite being not a purely rectilinear movement but parabolic, (a) the HT achieved the reliability criteria (intra-session), (b) the HT obtained "good" usefulness, and (c) MOB is a valid instrument to measure HT. This finding showed an ideal test for soccer players (HT), with a specific character (i.e., ball-presence, run-up phase, parabolic trajectory, unrestricted movement), using a cost-effective instrument, and applicable to all soccer fields (adjusted to the standardized lines in the soccer field), all of them backed-up by reliability, usefulness, and validity criteria. Practitioners should include the HT in the test batteries with the aim to know the authentic soccer player jumping ability, due to the relevance during the competition (~20% goals were scored by header), and the biomechanical (i.e., kinematic and kinetic) differences with other traditional standardized vertical jumps.

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Disclosure statement

None of the authors have any financial interest or benefit arising from the direct applications of their research.

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