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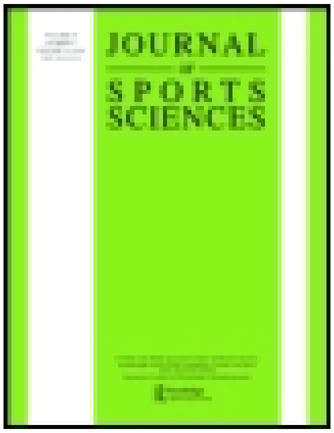

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The validity and reliability of an iPhone app for measuring vertical jump performance

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Abstract
The purpose of this investigation was to analyse the concurrent validity and reliability of an iPhone app (called: *My Jump*) for measuring vertical jump performance. Twenty recreationally active healthy men (age: 22.1 ± 3.6 years) completed five maximal countermovement jumps, which were evaluated using a force platform (time in the air method) and a specially designed iPhone app. *My jump* was developed to calculate the jump height from flight time using the high-speed video recording facility on the iPhone 5 s. Jump heights of the 100 jumps measured, for both devices, were compared using the intraclass correlation coefficient, Pearson product moment correlation coefficient (r), Cronbach's alpha (α), coefficient of variation and Bland–Altman plots. There was almost perfect agreement between the force platform and *My Jump* for the countermovement jump height (intraclass correlation coefficient = 0.997, $P < 0.001$; Bland–Altman bias = 1.1 ± 0.5 cm, $P < 0.001$). In comparison with the force platform, *My Jump* showed good validity for the CMJ height ($r = 0.995$, $P < 0.001$). The results of the present study showed that CMJ height can be easily, accurately and reliably evaluated using a specially developed iPhone 5 s app.

Keywords: *biomechanics, fitness, physical performance, strength*

Introduction

Vertical jump tests are among the most common means of evaluating physical fitness in various populations (Buchheit, Spencer, & Ahmaidi, 2010; De Villarreal, Izquierdo, & Gonzalez-Badillo, 2011; Rodacki, Fowler, & Bennett, 2002; Taipale, Mikkola, Vesterinen, Nummela, & Häkkinen, 2013). Though principally used to evaluate leg power in sports, such as basketball and football (Argus, Gill, Keogh, Hopkins, & Beaven, 2009; Duncan, Lyons, & Nevill, 2008; Hartman, Clark, Bemben, Kilgore, & Bemben, 2007), vertical jump tests have also been used to evaluate non-athletic populations (including children (Acero et al., 2011) and elderly people (Pereira et al., 2012)), particularly because vertical jump training has been reported to improve bone mineral density (Allison, Folland, Rennie, Summers, & Brooke-Wavell, 2013). Vertical jump tests have been proposed as important for talent identification purposes, with young elite athletes displaying higher values than their non-elite counterparts (Fry et al., 2006; Gabbett, Georgieff, & Domrow, 2007). Moreover, the height jumped, in addition to providing an indication of lower limb muscular power (Markovic, Dizdar, Jukic, & Cardinale, 2004) and neuromuscular fatigue (Buchheit et al., 2010; Sánchez-Medina & González-Badillo, 2011), has shown strong negative correlations ($r > -0.90$) with indices of exercise exhaustion and stress such as blood lactate (Sánchez-Medina & González-Badillo, 2011), ammonia (Sánchez-Medina & González-Badillo, 2011) and salivary-free cortisol concentrations (Balsalobre-Fernández, Tejero-González, & Del Campo-Vecino, 2014).

Several different approaches exist for measuring vertical jump height, with force platforms being considered the gold standard (Glatthorn et al., 2011; Requena, Requena, García, De Villarreal, & Pääsuke, 2012; Sayers, Harackiewicz, Harman, Frykman, & Rosenstein, 1999). Force platforms can measure vertical jump height using both time in the air and take-off velocity methods (Kibele, 1998; Moir, 2008). While take-off velocity is considered the most accurate method for measuring vertical jump height, time in

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the air method has been proved to be highly valid and reliable too, and most instrumental nowadays calculate jump height by measuring the flight time of the jump (Glatthorn et al., 2011; Moir, 2008; Requena et al., 2012). Although force platforms, accelerometers, contact platforms, infrared platforms and high-speed cameras (Casartelli, Müller, & Maffiuletti, 2010; Glatthorn et al., 2011; Requena et al., 2012) have been validated for measuring the flight time of vertical jumps, all of them have potential drawbacks. First, most of these devices are expensive for coaches and personal trainers and, as such, their use is largely confined to University laboratories and/or elite sports clubs. Second, these instruments can be bulky and often need specific computer software to analyse the data. Although the portability of this type of equipment has improved in recent years, it still provides a restriction which could affect its usability in field situations.

An inexpensive, portable approach for measuring vertical jump performance was validated recently (Balsalobre-Fernández, Tejero-González, Del Campo-Vecino, & Bavaresco, 2014), which combines the use of a low cost high-speed camera and license-free computer software to evaluate vertical jump height. However, the approach still requires the transfer of video footage from the camera to the software to calculate the vertical jump height, thereby slowing the evaluation process. This process usually takes 5 min of video transferring plus 30 s for each jump height calculation according to the authors.

Recently, Apple Inc. (USA) released the iPhone 5 s, an update of its smartphone, and one of its new features is a high-speed camera capable of recording 120 Hz. As such, with the development of an appropriate application (app), the phone has the potential to record high-speed videos and subsequently calculate jump height directly. However, there are no previous studies validating an iPhone app for measuring vertical jump height. The aim of the present study, therefore, was to analyse the validity and reliability of a specifically designed iPhone app (named: *My Jump*) for measuring vertical jump height.

Methods

Participants

Twenty recreationally active, healthy, sport sciences male students ($N = 20$, age = 22.1 ± 3.6 years, height = 1.81 ± 0.08 m, body mass = 74.0 ± 10.4 kg, countermovement jump – CMJ – height = 35.2 ± 5.4 cm) were recruited for this study. The study protocol complied with the Declaration of Helsinki for Human Experimentation and was approved by St Mary's University Ethics Committee. Written informed consent was obtained from each participant before participation.

Study design

The participants completed a standard 10-min warm-up composed of jogging, lower body dynamic stretches and vertical jumps. Then, each participant performed five CMJs on a force platform (Kistler 9287 BA, Kistler Instruments Ltd., Hook, UK) while being recorded with an iPhone 5 s (Apple Inc., USA) high-speed camera. All participants had experience on CMJ testing. Each jump was separated by a 2 min passive rest period. The app (named: *My Jump*), which was developed *ad hoc* for this study, calculated the flight time of the CMJ by identifying the take-off and the landing frames of the video, and then transforming it into a jump height using the equation described in the literature (Bosco, Luhtanen, & Komi, 1983): $h = t^2 \times 1.22625$, with h being the jump height in metres and t being the flight time of the jump in seconds. The same equation was also used to calculate jump heights from the force platform data.

Countermovement jump performance

Participants performed each CMJ with hands on their hips, starting from a static standing position and with their legs straight during the flight phase of the jump (Haekkinen & Komi, 1985). The landing was performed simultaneously with either feet keeping ankle dorsiflexion. Participants were instructed to jump as high as possible.

Equipment

App for the iPhone 5s. The app to calculate CMJ height was developed using the software (XCode 5.0.5 for Mac OSX 10.9.2; Apple Inc., USA) specifically designed to provide the necessary tools to write apps for the iPhone 5 s using Objective-C language. When finished, the app (named: *My Jump*) was installed on an iPhone 5 s, which includes a 120 Hz high-speed camera, at a quality of 720 p. *My Jump* was designed for analysing vertical jumps to allow the calculation of the time (in ms) between two frames selected by the user and subsequently to calculate the height of the CMJ using the equation described above.

To record the CMJ with *My Jump*, a researcher lay prone on the ground with the iPhone 5 s facing the participant (in the frontal plane), at ~1.5 m from the force platform, and zooming in on the feet of the participant. Two independent observers, with no prior experience on video analysis, were asked to select, with *My Jump*, the first frame in which both

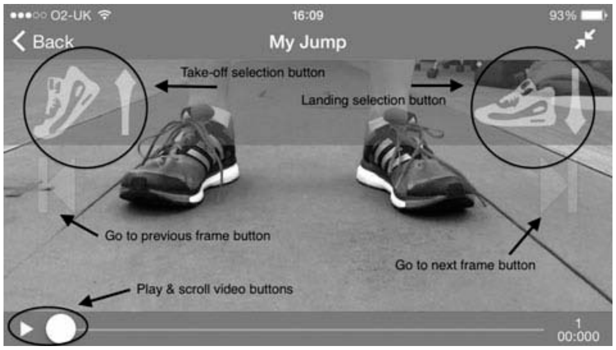

Figure 1. User interface of the app designed for this study.

feet were off the ground (take-off phase) and subsequently, the first frame in which at least one foot was touching the ground (landing phase). See Figure 1.

My Jump is available on the Appstore (Apple Inc., USA).

Force platform. The force platform (600 × 900 mm) recorded data at a sampling frequency of 1000 Hz and was used to measure the flight times of the CMJ at the same time as they were being recorded on the iPhone 5 s. The force platform was connected to a PC equipped with the software to analyse the force data (BioWare V5.2.2.4, Kistler Holding AG, Switzerland). Flight times from the analysis of the force platform data were used to calculate jump height using the same equation described earlier.

Statistical analyses

Several analyses were conducted to determine the reliability and validity of CMJ height using the app. First, to analyse the reliability of the app for measuring the CMJ height in comparison with the force platform data, the intraclass correlation coefficient (ICC) (2,1) was used. Second, to analyse the stability of the app when measuring the five CMJ of each participant, Cronbach's α and the coefficient of variation (CV) were used. Third, to complement the ICC analyses, Bland–Altman plots were created, which are known to give a good representation of the agreement between the two instruments (Bland & Altman, 1986). Fourth, to calculate the concurrent validity, the bivariate Pearson product moment correlation coefficient (r) was used. Finally, to analyse the reliability of the app between observers, an ICC was used. The level of statistical significance was set at $P < 0.05$. All calculations were performed using IBM SPSS Statistics 22 for Mac (IBM Co., USA).

Results

There was almost perfect agreement between the *My Jump* and the force platform CMJ jump heights (ICC = 0.997, 95% CI: 0.996–0.998, $P < 0.001$) for both observers, with a mean difference of 1.1 ± 0.5 cm (observer 1) and 1.3 ± 0.5 cm (observer 2) between instruments. *My Jump* values were significantly lower than those obtained with the force platform ($P < 0.05$). See Figure 2.

The app showed very good reliability for the five CMJ of each participant for jump height (observer 1: $\alpha = 0.997$, CV = 3.4%; observer 2: $\alpha = 0.988$, CV = 3.6%). Also, the Pearson product moment correlation coefficient showed almost perfect correlation between the app and the force platform measurements for jump height ($r = 0.995$, $P < 0.001$). See Figure 3.

Finally, when analysing the reliability of the app, almost perfect agreement between observer calculations was found for jump height (ICC = 0.999, 95% CL = 0.998–0.999, $P < 0.001$). The mean difference between observers was 0.1 ± 0.4 cm. See Figure 4.

Discussion

The purpose of this study was to analyse the concurrent validity and reliability of an iPhone app for measuring CMJ performance. *My Jump* was found to be highly valid and reliable in measuring the jump height of a CMJ in comparison with a force platform. Moreover, the data presented in Bland–Altman plots (Figures 2 and 4) showed that most of the CMJ values are close to the mean of the

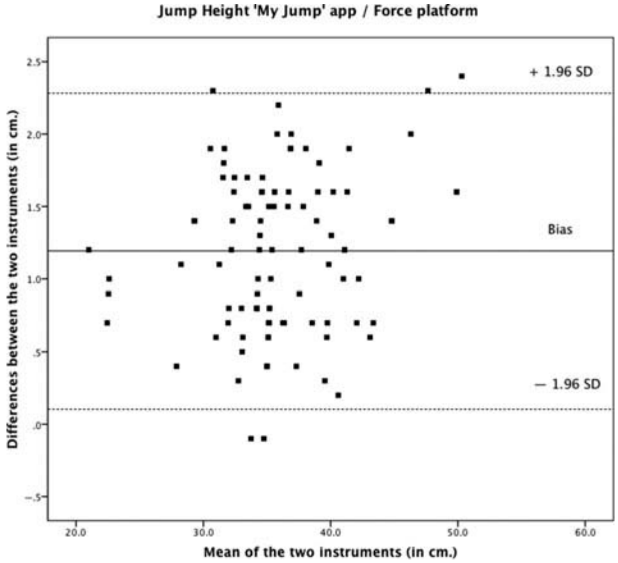

Figure 2. Bland–Altman plots for the force platform and *My Jump* app jump height data. The central line represents the absolute average difference between instruments, while the upper and the lower lines represent ±1.96 *s*.

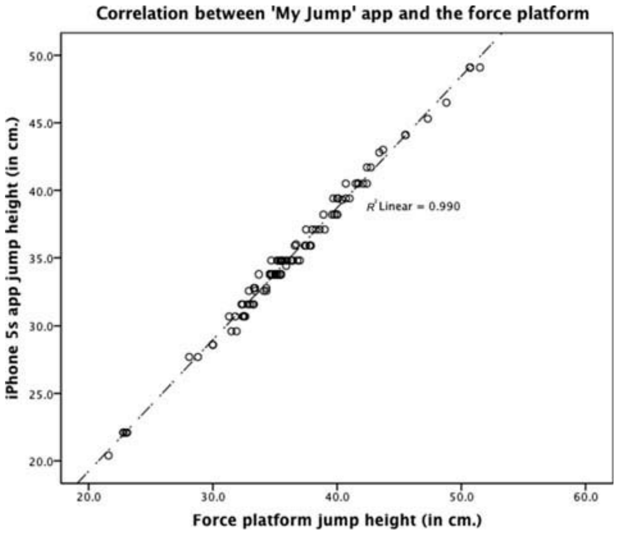

Figure 3. Concurrent validity between the force platform and *My Jump* app.

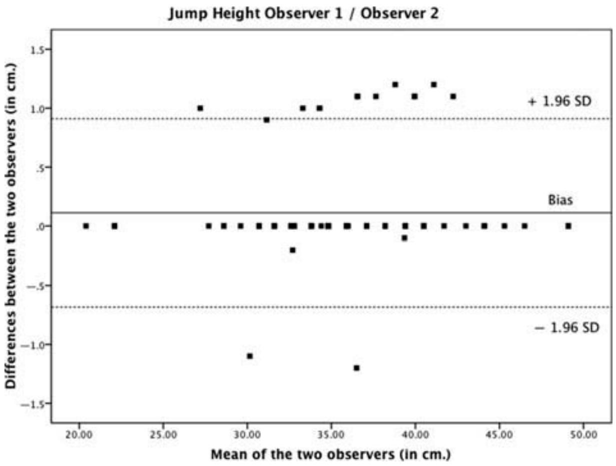

Figure 4. Bland–Altman plots between observers for jump height. The central line represents the absolute average difference between observers, while the upper and the lower lines represent ±1.96 *s*.

differences between instruments (1.1 ± 0.5 cm) or observers (0.1 ± 0.4 cm), thereby representing a high level of agreement (Bland & Altman, 1986). Specifically, the differences between observers on the measurements of the jump height were very small (about 1 mm), despite the fact that the take-off and landing frame selection had to be performed manually, which could increase the measurement error. Moreover, it is worth mentioning that the observers had no previous experience on video analysis, which highlights the usability of *My Jump*. Also, when analysing the reliability of *My Jump* for measuring the five CMJ for each participant, the results showed values that were very close to the ones obtained with the force platform (considered the gold standard for vertical jumps measurements (Duncan et al., 2008)), despite differences between devices in sampling frequency.

Previous studies have compared different technologies for measuring vertical jumps with force platform data. It has been demonstrated that an infrared platform has a difference of about 1.0 cm in comparison with a force platform at 1000 Hz (Glatthorn et al., 2011). Also, it was shown that an accelerometric system (Myotest SA, Switzerland) has a mean difference of 3.6 cm in comparison with a force platform at 1000 Hz (Choukou, Laffaye, & Taiar, 2014), higher than the app analysed in this study. Probably, the most accurate systems for measuring vertical jump height (besides force platforms) are professional high-speed cameras (Balsalobre-Fernández et al., 2014; García-López et al., 2005; Requena et al., 2012). For example, a professional high-speed camera recording at 1000 Hz has a difference of just 1.3 ms of flight time in comparison with a 1000 Hz force platform (Requena et al., 2012). Taking into account that information, the accuracy of *My Jump* (about 8.9 ms of flight time or 1.2 cm of jump height) compares well with much more expensive and less portable devices. Moreover, the rapid advancement of new technologies suggests that, in the near future, smartphones will include cameras with higher recording frequencies that will reduce the measurement error of the *My Jump*. In fact, after we submitted the first version of this manuscript, Apple announced the new iPhone 6 featuring a 240 Hz high-speed camera. Indeed, it has been suggested that smartphones apps, because of their popularity, affordability, portability and advanced technology, will soon be a commonplace for measuring variables (such as CMJ height) associated with physical performance and health with great accuracy (Bort-Roig, Gilson, Puig-Ribera, Contreras, & Trost, 2014).

The major drawback of *My Jump* is that, since it records videos at 120 Hz, there is a chance that the take-off and/or the landing frame will not be recorded. The equation for the calculation of the jump height uses the flight time squared, which means that the measurement error increases with longer flight times (Balsalobre-Fernández et al., 2014). However, the highest CMJ measured on this study, which was higher than an average professional basketball player (Alemdaroğlu, 2012) (51.5 cm), had a difference of only 1.6 cm with respect to the force platform. As such, *My Jump* is able to measure jump heights accurately for most populations, including trained athletes, and requires no prior video analysis experience. This is the first study that validates a commercial iPhone app for measuring vertical jump height.

Conclusions

The ability to evaluate and monitor CMJ ability is important in areas of health, talent identification and sporting performance. The results of the present study showed that CMJ height can be easily, accurately and reliably evaluated using a specially developed iPhone 5 s app (named: *My Jump*) which is available on the Appstore (Apple Inc., USA). These findings could help coaches and trainers who wish to monitor the vertical jump ability of their athletes or clients in a valid and economic way.

Conflicts of interest

The first author of the article is the co-designer of the app mentioned. The data from the app were obtained from two independent observers not related to the app development.

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