Validity and reliability of portable gym devices and an iPhone app to measure vertical jump performance

Jericho F Wee [1], Danny Lum [2], Marcus Lee [1] , Quintin Roman [1] , Ivan Ee [1] , Haresh T Suppiah [1]

[1]National Youth Sports Institute, Singapore, and [2]Singapore Sport Institute, Singapore

Validity | Monitoring | Jump Performance | Portable devices

Headline

The countermovement jump (CMJ) is the most used and validated assessment of athletes' lower limb explosive power (1, 2). Velocity and power may be used to determine athletes' mechanical capability (3). Technology has made it affordable and convenient to measure CMJ parameters. It is important that practitioners use cost-effective, valid and reliable instruments to monitor high-performance athletes.

Aim. The purpose of this report was to determine the concurrent validity and reliability of three portable instruments for measuring CMJ performance.

Design. Evaluation Study

Methods

Athletes. Fourteen Singaporean male (n = 3; body mass = 71.0 ± 6.7 kg; height = 179.6 ± 5.0 cm) and female (n = 11; body mass = 62.5 ± 8.3 kg; height = 168.1 ± 7.8 cm) youth athletes (age = 19.7 ± 0.8 years) from athletics (n = 1), beach volleyball (n = 2), football (n = 1), handball (n = 1), netball (n = 7), rugby (n = 1), and volleyball (n = 1) participated in this study. Athletes ranged from varsity (n = 5) to national athletes (n = 9). All participants were proficient in the CMJ. Ethical clearance was granted by the Singapore Sport Institute Institutional Review Board (PH-EXP-023), and all participants and their parents/guardians provided informed consent.

Methodology. Athletes had their height taken with shoes and completed a standard warm-up consisting of 5-minute self-paced cycling and lower body dynamic movements. Athletes were then weighed on the force platform before carrying out two submaximal practice jumps and three recorded maximal CMJ, interspersed by two minutes. Athletes were instructed to perform their best effort for each jump. Detailed descriptions of the instruments and athlete preparation can be found below.

PUSH Wearable Device (PUSH Inc., Canada): The PUSH 1.0 (Firmware 1.2.1, App Version 4.2.0) was positioned over the spine of the participants' torso (under the last rib) to measure the jumps.

My Jump 2 App: A researcher with anatomical understanding measured and recorded the athletes' leg lengths in the app. Video recordings of the jumps were carried out with an iPhone 6s 1.5m from the front, as recommended in previous studies and the application developer (4). The anterior iliac spine was used, instead of the greater trochanter, to measure the vertical distance (hs) from the initiation of the concentric phase of CMJ (5). Both measurement sites were recommended in the app. This was attributed to the difficulty of palpating for the greater trochanter due to fatty deposits around the hips of female athletes (6).

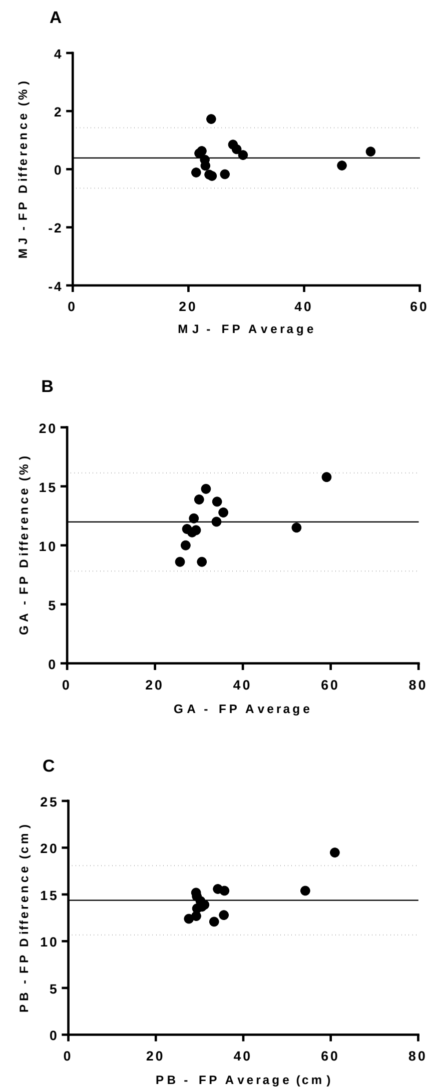

Fig. 1. Bland-Altman plots of the differences between the criterion (force plate) and; (A): MJ, (B): GA, and (C): PB for jump height (cm). Dotted lines represent the 95% LOA. Solid black line represents the mean bias between instruments.

GymAware (Kinetic Performance, Australia): The device was positioned directly behind the force plates. The cable was then attached to the back of a Hammer Strength Training Vest worn by the participant, over where the Push device was positioned on the torso.

Table 1. CMJ measurement values by all instruments

	FP (Mean ± SD)	MJ Mean ± SD	GA Mean ± SD	PB Mean ± SD
Jump Height (cm)	27.9 ± 9.3	28.3 ± 9.3	39.9 ± 10.3	42.3 ± 10.7
Mean Velocity ($m.s^{-1}$)	1.30 ± 0.18	1.16 ± 0.17	1.29 ± 0.19	1.22 ± 0.19
Mean Power (W)	1536 ± 453	1605 ± 658	1130 ± 258	1331 ± 389

Table 2. CMJ measurement values by all instruments

	MJ	GA	PB
JH Pearson's r	0.998	0.983	0.992
JH Bias (cm)	0.39 ± 0.25	12.0 ± 1.0	14.4 ± 0.9
JH LOA (cm)	-0.65, 1.43	7.83, 16.1	10.7, 18.1
JH TEE (cm)	0.55	1.79	1.22
JH TEE (%)	2.3	6.6	4.6
MP Pearson's r	0.852	0.577	0.988
MP Bias (W)	68.1 ± 170.9	-406.1 ± 175.2	-205.1 ± 43.6
MP LOA (W)	-639.7, 775.9	-1131.0, 319.2	-385.4, -24.70
TEE (W)	247.1	385.2	73.5
TEE (%)	15.3	24.3	5.6
MV Pearson's r	0.989	0.916	0.979
MV Bias (m.s-1)	-0.14 ± 0.01	-0.01 ± 0.04	-0.09 ± 0.02
MV LOA (m.s-1)	-0.20, -0.09	-0.16, 0.14	-0.17, -0.01
TEE (m.s-1)	0.03	0.08	0.04
TEE (%)	2.3	6.1	3.2

Bias values are mean ± 90% CL. LOA values are expressed as upper and lower values

PASPORT Force Platform (PASCO, USA): The force platform was used as the criterion instrument and has been validated against the Kistler force plate (7) and analysed by the ForceDecks software (Vald Performance Pte. Ltd., UK).

Statistical analysis

Concurrent validity of the *PUSH (PB)*, *My Jump 2 (MJ)* and *GymAware (GA)* against the *force plate (FP)* was determined by Pearson correlation coefficients. The magnitude of correlation between the instruments against FP was assessed using the following thresholds: <0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; and 0.9–1.0, almost perfect (8-10). The mean bias and typical error of estimate (TEE) were also calculated and interpreted as recommended by Hopkins (10, 11). Interpretation of mean bias was done using the modified Cohen effect sizes (ES): <0.20, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0, extremely large (10). If the 90% CL crossed zero, small ES were deemed unclear (12). Bland-Altman plots were constructed to represent the bias and 95% level of agreement between the instruments and FP. Within-testing-session typical error (TE) was also expressed as coefficients of variation (CV) (8, 13).

Results

Jump Height. Pearson correlations were *almost perfect* for all instruments when compared to FP (Table 2). Random errors based on TEE (Table 2) were *trivial* for MJ and small for GA and PB. There was a *trivial* overestimation from MJ (ES=0.04), whereas, *moderate* overestimations were observed from both GA (ES=1.29) and PB (ES=1.55). Figure 1 highlights the mean bias and 95% LOA of all devices. Mean CVs for MJ, GA and PB for the three consecutive jumps were 3.6%, 3.7% and 4.7%, respectively.

Mean Power. Pearson correlations were *very large*, *large* and *almost perfect* for MJ, GA and PB, respectively when compared to FP. Random errors based on TEE (Table 2) were *moderate*, *very large* and *small* for MJ, GA and PB respectively. MJ (ES=0.15) had an *unclear* bias, whereas *small* underestimations from both GA (ES=-0.90) and PB (ES=-0.45) were observed. Figure 2 highlights the mean bias and 95% LOA of all devices. Mean CVs for MJ, GA and PB for the three consecutive jumps were 3.8%, 6.8% and 7.1%, respectively.

Mean Velocity. Pearson correlations were *almost perfect* across all test instruments when compared to FP (Table 2). Random errors based on TEE (Table 2) were *moderate* for GA and *small* for MJ and PB. GA (ES=-0.08) had an unclear bias. PB (ES=-0.47) and MJ (ES=-0.77) exhibited *small* and *moderate* underestimations, respectively. Figure 3 highlights the mean bias and 95% LOA of all devices. Mean CVs for MJ, GA and PB for the three consecutive jumps were 1.9%, 3.1% and 3.1%, respectively.

Discussion

MJ is valid and reliable to measure jump height with trivial overestimations. Its accuracy in measuring jump height is in line with literature (4, 14). To the best of knowledge, while the app itself has not been validated for MV and MP, the computation formula (5), from which MJ is based on, has demonstrated validity and reliability for MP and MV (3). In this study, MJ was very largely associated with, and not different from FP for MP. MJ demonstrated moderate underestimations and almost perfect association with FP for MV. This bias may have resulted from the selection of the anterior iliac spine instead of the greater trochanter.

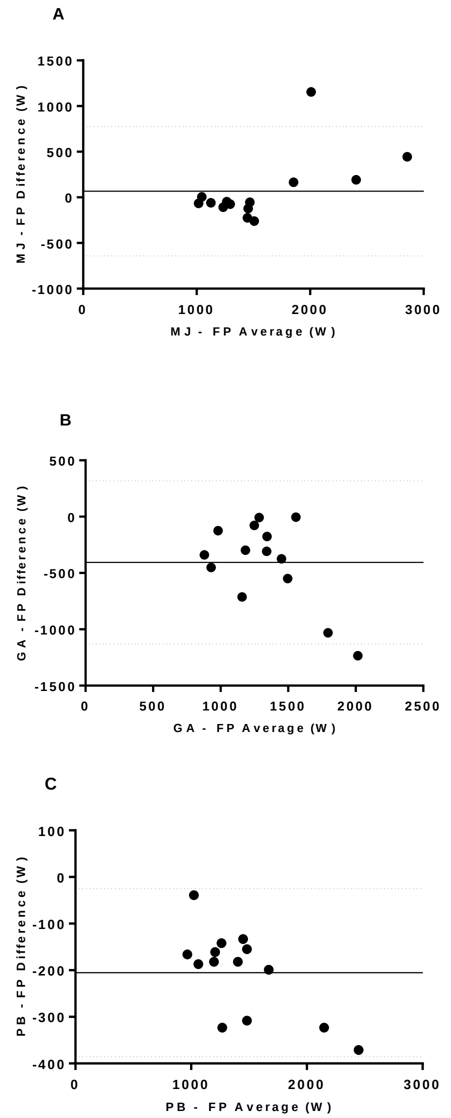

Fig. 2. Bland-Altman plots of the differences between the criterion (force plate) and; (A): MJ, (B): GA, and (C): PB for mean power (W). Dotted lines represent the 95% LOA. Solid black line represents the mean bias between instruments.

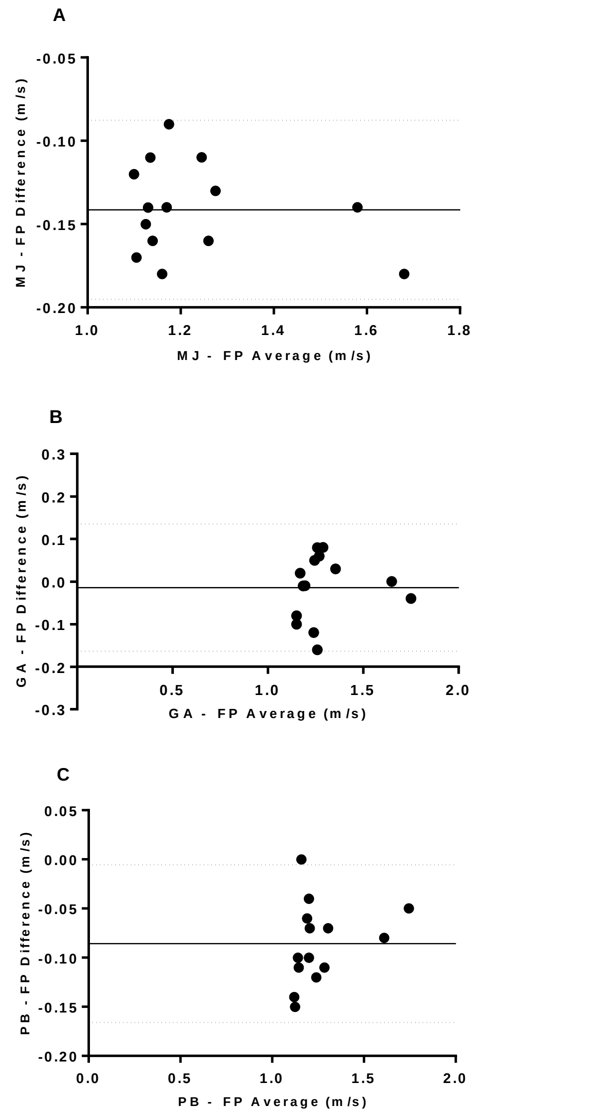

Fig. 3. Bland-Altman plots of the differences between the criterion (force plate) and; (A): MJ, (B): GA, and (C): PB for mean velocity (m.s-1). Dotted lines represent the 95% LOA. Solid black line represents the mean bias between instruments.

In this study, GA had large overestimations and small random errors, similarly reported previously for jump height (9). The same study found high inter-day reliability, suggesting that despite its questionable validity, it may be used to monitor athletes' jump performance over time. GA demonstrated almost perfect associations with FP and with no difference for mean velocity. This is the first study reporting underestimations by GA in MP for the CMJ. Other studies have reported overestimations of 11% in peak power and 30% in peak velocity compared to force plates (15). A probable cause was that the cable was not attached to the waist position which past studies have used (9, 16).

This is the first study validating the PB in the CMJ. PB moderately overestimated jump height. Other studies found similar overestimations using accelerometery in jump tests because accelerometers consider flight time (FT) as a lapse of time between the peak positive and minimum negative velocities (17, 18). This results in an underestimation of the take-off time, causing overestimations of FT and JH. PB showed high validity with small underestimations from FP for MV and MP. However, previous studies have reported overestimations in MP and MV in other accelerometric devices (17). In this study, jumps were performed without arm swing. As such, the eccentric phase is used to maintain balance rather than maximising the shortening phase (19). This makes detection of the start of concentric phases difficult which affects the initial velocity and power (17). This may explain the underestimations of MV and MP.

This study compared different instruments for CMJ testing and found MJ valid and reliable for the across all CMJ measures investigated in this study, while PB is valid and reliable to measure MP and MV of CMJ. The opinion of this paper is that GA should not be used interchangeably due to the reported bias in literature but may be used for monitoring athletes over time if used exclusively.

	Advantages	Challenges	Suggested uses
My Jump 2	• Affordable • Portable • Accuracy of jump measures • Saves and monitors progression overtime • Available on both Android and iOS	• Requires practice of anthropometric measures of limb length • Need for continuous updating of anthropometric profiles during periods of growth (adolescence)	• Jump testing (CMJ, squat jump, drop jumps, etc.)
GymAware	• Portable • Easy to use • Displays many absolute and relative measures	• Requires waist harness • Only measures linear movements • Questionable validity in unloaded CMJ in literature	• Assessing velocity and power of uniplanar resistance exercises
PUSH	• Affordable • Portable • Easy to use with video tutorials • Free app download • Coach dashboard for athlete data management	• Subscription required for coach dashboard feature • Temporal bias for unloaded jump tests	• Velocity-based training prescription

Fig. 4. Summary of considerations for practitioners for the *My Jump 2*, *GymAware* and *PUSH*.

Limitations

- The selection of the anterior iliac spine over the greater trochanter to measure hs for MJ. Future studies should validate the choice of site recommended in MJ to measure the hs, which is required to determine velocity and power.
- The site of attachment of the cable was on the back of a vest due to the unavailability of a waist harness. Future studies should determine the effect of different attachment positions (e.g. torso vs waist) in measuring CMJ using LPT.

Practical applications

- MJ is a convenient means to collect CMJ data from athletes quickly and with little cost, and only requires a smartphone with a slow-motion camera where "gold standard" force plates prove expensive and/or bulky.
- Accelerometers such as the PB may be more appropriate for prescribing loads via velocity-based training during strength and conditioning sessions instead of assessing athletic power in jump tests due to the aforementioned biases (20, 21).
- Technology has empowered practitioners to monitor athletic performance conveniently. Practitioners should consider the validity and the caveats of each method. This paper includes a summary of considerations for the MJ and PB.

Dataset

Dataset available on SportPerfSci.com

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