A Project entitled

The validity and test-retest reliability of "My Jump 2", "HomeCourt" & "Takei Vertical Jump Meter" for measuring countermovement jump

Submitted by

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Declaration

I, *Pun Wai Yan* declare that this research report represents my own work under the supervision of *the validity and test-retest reliability of "My Jump 2", "HomeCourt" & "Takei Vertical Jump Meter" for measuring countermovement jump* and *Dr. Chow Chi Ching, Gary*, and that it has not been submitted previously for examination to any tertiary institution.

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Abstract

Purpose: This study aims to investigate the validity and test-retest reliability of the remote assessments of countermovement jumps via three remote assessments.

Methods: Thirty physically active healthy students from the Education University of Hong Kong (EdUHK) (age 23.03 ± 1.67 years; body mass: 61.89 ± 9.82 kg; height: 167.86 ± 6.27 cm) were recruited for the study voluntarily. The participants performed three countermovement jumps (CMJ) in a session with two days interval for test-retest reliability. The jumps were recorded and assessed by the Takei Vertical Jump Meter (the Takei) and two mobile devices "HomeCourt" and "My Jump 2" at the same time to measure the validity.

Results: There are high intraclass correlation coefficients (ICCs) were perceived (within-day mean = 0.85; between-day mean = 0.86, My Jump 2, HomeCourt & the Takei) in all measurements and factors. There was no significant systematic bias ± random errors ($p > 0.05$) between test-retest. Similar coefficients of variation (CV) were shown in all measurements. The Takei showed the lowest CV (< 3%) in both factors. Acceptable and good correlations were observed between three measurements (r= 0.81.- 0.87). The Takei performed the lowest minimal detectable change (MDC ± 4.59cm) result in the between day trial compared with others.

Conclusion: This study finds My Jump 2, HomeCourt and the Takei showed reliable and valid information on the CMJ performance. To compare the MDC of the Takei, remote assessments require larger improvements of CMJ. It can be concluded that the remote assessment is still in the development process. (254 words)

Keywords: Countermovement jump, remote assessment, test-retest reliability, validity, ICC, MDC

Introduction

The COVID-19 pandemic and spread rapidly, the government has tried to delay the spread of COVID-19 in Hong Kong by the following restrictions, school closures, social distancing, closures of gym rooms and sports centers. All the sports and outdoor activities have been suspended since 2020. More than that, some of the international competitions such as Olympic 2020 was also suspended due to the COVID-19 pandemic. People's daily lifestyles are affected, such as sports activities. Even professional and amateur athletes, all the training and competitions were stopped. Home workout becomes the popular way to exercise for maintaining good strength and conditioning. Government restrictions limited the coaches to monitor athlete's muscle strength directly. To monitor the athletes' strength and conditioning level, remote assessment might not only bring the massive change in the sports field, but also in the public use, such as school level.

Remote assessment

Under the COVID-19 pandemic, the development of sports technology brings lots of benefits to the society. In the research from Dijkstra et al. (2020), it provided the definition of "eHealth" and "mHealth" which are definitely related to remote assessment. The information released from the World Health Organization (WHO) on April 2020, it defines eHealth as "medical and public health practices supported by electronic processes and communications." The Qatar's Ministry of Public Health (MOPH) extends WHO's definition of eHealth to "enable healthcare with information and technology that supports the delivery of healthcare and clinical research. Overall, technology in health and medical enable to connect people and processes to improve the level of patient care in the "medical" joint alliance. "mHealth" refers to an eHealth

application by using a mobile device. By using the mobile devices, people do not need to do the face-to-face assessment, as it might take a long time, such as reducing the travelling time. Remote assessment can bring convenience that people can do the assessment during their free-time and make the process much efficient and maintain the necessary social distancing. More than that, people have the flexibility to choose where the assessment to take. However, as mentioned by McMahon (2017), validation of the remote assessment is needed prior to practical application to the field and public. Remote assessments not only have been developing in the sports and exercise medicine aspect, but also in primary health care since the COVID-19 pandemic (Dijkstra et al., 2020; Greenhalgh et al., 2020). Physical therapists, coaches and athletes are available to monitor the sports performance via the remote assessment, to reduce the face-to-face interaction and the risk of infection. The public is more concerned about their personal health. Furthermore, the population of different types of sport mobile applications are increasing under the COVID-19, such as Strava, HomeCourt, Nike Running and Apple Health etc. These applications provide the platform for users to track, record and analyze their personal sports activities and performance. More than that, the users are available to share their workout results and photos with their friends or upload on the social media. But, a valid and reliable sports mobile application can provide much accurate data of personal performance. Therefore, the reliability and validity of remote assessment is important information for the public to choose the right sports mobile application.

Nowadays, there are lots of sports mobile applications for the public to test the jumping performance and follow their workout program, such as My Jump 2 and HomeCourt. Those two mobile applications provide different vertical jump measurements and other skills training. More than that, the Takei Vertical Jump

Meter (Takei) is also a handy jump-testing instrument from Japan. These three instruments are available to test the CMJ performance in the field or at home. Several researches have proved that My Jump 2 is valid and reliable compared with force platform (gold standard) (Bogataj, Š et al, 2020 & Wee et al, 2019). However, the validity and reliability of HomeCourt and Takei have not been tested yet. According to McMahon (2017), a lack of studies have validated the Takei so the jumping result cannot be valued. In this study, My Jump 2 mobile application, the only validated assessment from others study, will be selected to compare the validity and test-retest reliability of other two testing instruments.

Countermovement Jump

Vertical jump, convenience testing, is the common test to assess physical fitness level, particular to explosive strength and estimate the capacity and power of anaerobic metabolism (Garnacho-Castaño et al, 2021). Several studies were investigated the similar topic with present study, the squad jump (SJ) and countermovement jump (CMJ) are the most common two jumping test to investigated in the research (Bogataj et al., 2020; Gallardo-Fuentes et al., 2016; Stanton et al., 2017). The CMJ is usually selected to be the jumping technique, so was selected in this study as well. According to Wee et al (2019), CMJ is the most commonly used and validated testing to assess the individual's lower limb explosive power. Most sports require explosive movement, such as basketball, soccer, handball and tackle rugby. CMJ can show the athlete's explosive strengths, which includes a stretch-shortening cycle in muscle to perform fast and maximum effort jumps. It is important to pay attention to the tendons of the muscles interactions to better understand the mechanisms that explain the enhanced CMJ performance. In general,

the extension shortening cycle is vaguely described as a step of muscle extension followed by shortening.

However, the muscle elements that stretch and contract are indistinguishable and can be misleading. For example, it is usually supposed that there is an eccentric effect (e.g., active elongation) of the leg muscle bundles during the downward movement of the CMJ. According to Van Hooren & Zolotarjova (2017), they suggested that the future study referring to the CMJ's downward and upward phases rather than the CMJ's eccentric and concentric phases and avoiding the use of terms that include eccentric phases, for example eccentric use. Furthermore, it is problematic to attribute the difference between CMJ and SJ to the effective use of the eccentric phase and the mechanisms that occur during eccentric myocardial action, as the CMJ may not have an eccentric phase. Conversely, the better acute performance of CMJ may be the result of other mechanisms.

According to the earlier study, it has stated that CMJ is a reliable test to assess the explosive strength in the lower extremity extensor muscles in athletes (Slinde et al, 2008). According to the research from Garnacho-Castaño et al. (2021), jumping performance has been extensively adopted in sports training to monitor and measure the explosive strength level in several sports. The changes of the CMJ height can provide coaches important information to arrange relevant training for performance enhancement.

This study aimed to assess the test-retest reliability and validity of My Jump 2, HomeCourt and the Takei to measure the CMJ height and evaluated the agreement of three assessments. This study hypothesized that the remote assessments are valid and reliable tools to measure the CMJ performance. These assessments would be able to be promoted in sports field, school or public use.

Methods

Participants

Thirty physically active and healthy EdUHK students were recruited for the study voluntarily (male: n=14; female: n=16; age 23.03 ± 1.67 years; body mass: 61.89 ± 9.82 kg; height: 167.86 ± 6.27 cm). All participants were injury free and completely acquainted with the CMJ. There are some inclusion criteria which are important for this study. All subjects were currently participating in the sports which include explosive movement, such as tackle rugby, basketball, soccer, volleyball or taekwondo. All of the participants were physically active and were not carrying any injury during the test.

Before the test started, all participants completed the Individual Physical Activity Questionnaire Short Form (IPAQs) to assess their current physical activity (PA) level in last seven days. Participants were asked their physical activities that they do as part of their daily lifestyle. The form was asked about the total time and day that individual spent in physical activities in the last seven days. Each individual has to review their activities during a week. The questionnaire separates into different level of activities, which are vigorous activities, moderate activities, walking and sitting.

Each participant needs to calculate their physical activities day and minutes. According to Forde (2018), participant who are engage three days in the vigorous activities or more than 1500 MET minutes a week could be scored in high PA level of participation. Participant who are participating a minimal 600 MET minutes a week of physical activities would be considered as moderate PA level of participation. Lastly, participant who are not achieving any of criteria for either high or moderate PA levels would be considered as a low PA level.

Based on the results of IPAQs, all participants had a high level of participation in physical activity. The purpose of the study and the experimental procedures were informed to all participants before the test. All written consent was collected from each subject. The study was approved by the Research and Development Office of the EdUHK.

Procedure

Each participant was requested to attend two testing sessions, and participants performed three CMJ in each session. The second session was held 24 hours later (3 jumps per participant in each session, 6 jumps in the whole test). Participants were wearing the tight sweatshirt during the tests. Subject personal information was input on the My Jump 2 apps, such as name, body weight, height, leg length and height of 90-degree. Before the test began, the investigator measured the leg length and the height at 90 degree of each subject. To measure the leg length, it is measuring the distance from the greater trochanter of the femur to the tiptoe. Each subject needs to lay down on the back with full ankle plantar flexion. To measure the height at 90degree, participant was requested to squad down about 90-degree, investigator measured the distance from the great trochanter of the tight and the ground in an optimal knee-flexed position. Participants began with a 5 minutes familiarization session to introduce and practice the CMJ movement. After that, 5 minutes dynamic stretching, and warm-up was provided to each participant. The rest time after the warm-up was 2 minutes. The test began after the rest, 2 minutes recovery time was provided between each jump. Each jump was recorded with the app of My Jump 2 and HomeCourt, and the Takei at the same time. A total of 180 jumps were collected in this experiment.

Participants were required to stand on the Takei rubber mat with the bell and hands on their hips. Two iPad devices (iOS 14.4) were set up with the same 75 degree and a distance of 3 meters on the plastic bracket in front of the participant (Figure 1 picture). iPad with label no.2 (iPad 2) recorded the jump height by using My Jump 2; iPad with label no.3 (iPad 3) recorded the HomeCourt result. The jumping height results were the main data in this study.

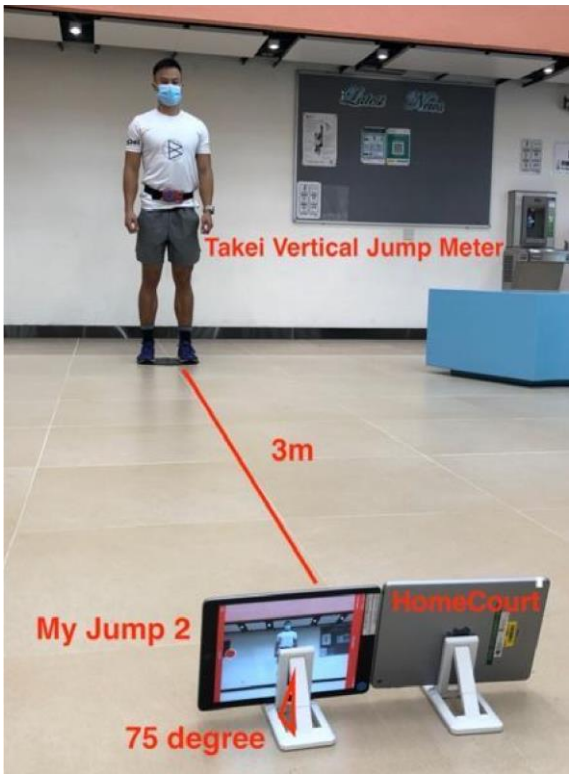

Figure 1: Demonstration the set-up of My Jump 2, HomeCourt and the Takei during the countermovement jumps.

Equipment

"My Jump 2" Apps

My Jump 2 (version 6.1.4) is a mobile application, which is designed and released by Prof. Carlos Balsalobre. It is requested to purchase from the App Store.

It is mainly calculating the jumping height by recording the high-speed video (Bogataj, Š et al, 2020). The video recording of the jumps would be recorded with an iPad or an iPhone. Before measuring the jump height, My Jump 2 required the investigator input the tester's body weight, leg length and height of 90 degree. The app measures the push-off distance of the range of motion during the tester's pushing against the ground to jump. The legs length minus at the tester's hip at the beginning of jump would be calculated. The test operator has selected the take-off and landing frame of the video manually (Figure 2). The jumping result is displayed with two decimal places (Figure 3). Several papers have used My Jump 2 in scientific academic study. It was proved that My Jump 2 app is a valid and reliable tool to measure the jump height and has been adopted in the sports field training.

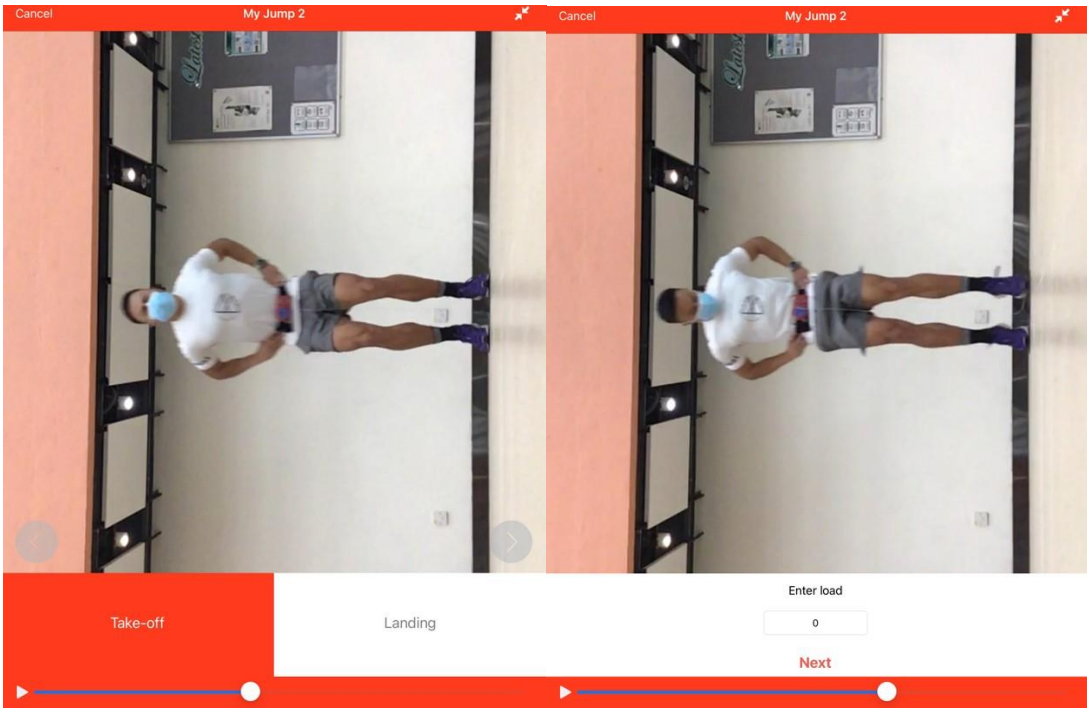

Figure 2: the take-off and landing on My Jump 2.

Figure 3: The jumping result displayed on My Jump 2

"HomeCourt" Apps

HomeCourt (version 3.14.5) is a mobile application released by the NEX Team Inc. in 2017, and partnership with the NBA. The app is free to download from Apple App Store. HomeCourt provides different basketball training on the app, such as agility, reaction, shooting and dribbling. It uses artificial intelligence (AI) and image recognition technology to create on-the-spot analyses and then manufactures the result. HomeCourt is also able to test the vertical jump performance (Figure 4). The jumping can be recorded and assessed by an iPad or an iPhone. Since the COVID19 pandemic, HomeCourt has become a popular app in public use to test agility and train reaction skills.

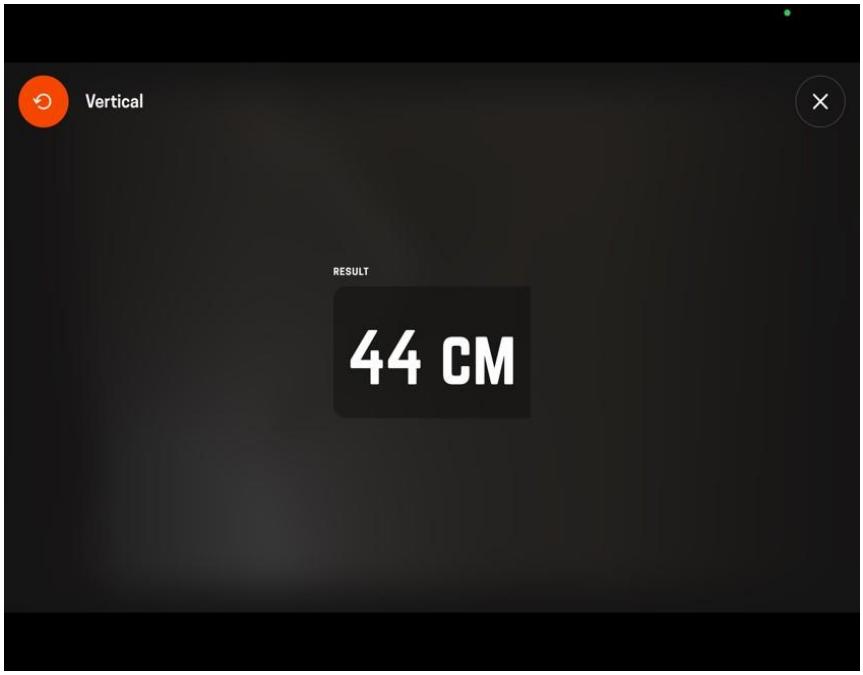

Figure 4: The jumping result displayed on HomeCcourt

“The Takei Vertical Jump Meter: Jump MD”

The Takei is a product produced by the Takei Scientific Instrument Co., Ltd, which is an easy tool to measure the jump performance. The tester stands on the rubber mat and fits the belt around the waist. The belt connects to the mat with a measurement cord, it is used to measure the vertical jump height. The cord must roll tight from the belt and mat and reset the LCD screen to 0 cm before the jump. The height of jump measurement will be displayed on an LCD screen (Figure 5).

According to McMahon et al. (2017), the Takei is a linear position transducer (LPT). According to Wadhi et al (2018), the LPT is the portable and practical measurement method that measures the displacement and velocity of an object using the optical encoding technology. The LPT is becoming common to use in strength and conditioning fields.

Figure 5: The jumping result displayed on the Takei Vertical Jump Meter

Jumping technique

Participants needed to place their hands on the hips throughout the whole jump, starting with the upright position before they began the CMJ test. They were requested to perform a quick downward movement (approximately 90 degree of knee flexion) and then a fast-upward movement to jump as high as possible. The knee and hips needed to completely extend during the flight time. Both legs and hips have to be completely extended during the flight time. Participants were asked to maintain the landing with both feet and located in the same place (Figure 6). All participants were requested to perform maximum effort on each jump before they start each trial. Each jump was checked by the investigator. Inappropriate jumps were not considered for the statistical analysis.

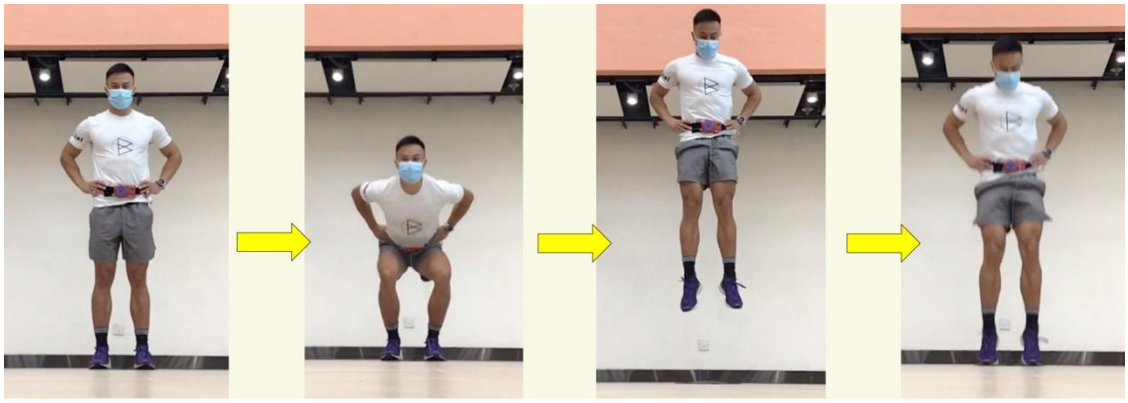

Figure 6: Countermovement jump movement.

Statistical Analyses

All statistical tests and graphics were analyzed using the SPSS software version 26.0 for Mackintosh (SPSS, Chicago, IL). Data normality was checked by the Shapiro-Wilk test. Descriptive statistics were presented in mean, standard deviation (SD) and 95% confidence interval (CI).

The intraclass correlation coefficient (ICC) with a 95% CI was used to assess the three test-retest reliability in between My Jump 2, HomeCourt and the Takei. Also, the typical error was revealed as coefficient of variation (CV%). According to Koo & Li (2016) mentioned about the ICC analysis, single measure, two-way mixed, absolute agreement parameters were used (ICC 3,1). The researcher believed that the subjects were much familiar with the CMJ movement on the last jump. Therefore, this study sorted out the last two jumps of each subject on day 2 trial to analyze the within-day reliability and last jumps of each subject on day 1 and day 2 to analyze the between-day reliability. Based on Portney and Watkins study in 2009, they were examined the ICC value between 0.50 - 0.75 indicates acceptable, 0.75 - 0.90 indicates good reliability, over 0.90 indicates excellent reliability.

The Pearson's product-moment correlation coefficient (*r*) was used to monitor the concurrent validity. It is used to examine the strength of relationship between three instruments (Cruvinel-Cabral et al. 2018). All the jumps recorded (180 jumps) on each measurement were used to calculate the concurrent validity. Evans (1996) stated that the range of correlation strength, r = 0.40 - 0.59 indicates moderate correlation, 0.60 - 0.79 indicates strong correlation, over 0.80 indicates very strong correlation.

Minimal detectable change with 95 % confidence level ($MDC_{95\%}$) also had been calculated in this study. Furlan & Sterr (2018) stated that $MDC_{95\%}$ is a mathematical measure of the smallest amount for the measurement to be considered a real improvement. It was calculated by the standard error of measurement (SEM), the formula is 1.96x $\sqrt{2}$ SEM. The lowest score of the detectable change which means to be greater than within subject variability and measurement error. Significant was set at *p* value smaller than 0.05 level.

Results

All participants were completed all the CMJ trials successfully. Therefore, there were a total of 180 jumps were analyzed. But the research's investigator had sorted out specific data to evaluate the test-retest reliability and validity.

ICC analysis demonstrated good and excellent reliability in both within-day (ICC = 0.74 - 0.96) and between-day results (ICC = 0.80 - 0.96) among three measurements. **Table 1** displays the mean, SD of CMJ results in both within-day and between-day, ICC value and the lower and upper limit of the 95% confidence interval and CV%.

The Takei performed the excellent test-retest reliability (ICC = 0.96) and lowest CV% in both within-day (CV% = 2.96) and between-day (CV% = 3.07).

There were no significant test-retest differences ($p > 0.05$) were observed in each assessment. The $MDC_{95\%}$ results also shown in Table **1**, showed that the Takei requested the lowest detectable change when compared with the other two assessments ($MDC_{95\%} = 4.59$).

All the CMJ results from each measurement were used to calculate the concurrent validity examined by the Pearson's product-moment correlation coefficient. As the results shown in Table 2, all assessments demonstrated very strong correlation between the My Jump 2 and HomeCourt ($r = 0.85$, $p < 0.01$), My Jump 2 and the Takei ($r = 0.87$, $p < 0.01$), HomeCourt and the Takei ($r = 0.81$, $p < 0.01$).

Table 1. Test-retest reliability of My Jump 2, HomeCourt and Takei Vertical Jump Meter

	Mean (cm)	SD (cm)	ICC (3,1) (95% CI)	CV%	SEM	$MDC_{95\%}$(cm)
Within-day (day 2: last two jumps)						
My Jump 2	40.88	7.44	0.85 (0.72 – 0.93)	5.48	2.86	7.92
HomeCourt	46.72	7.01	0.74 (0.41 – 0.88)	5.91	3.57	9.88
Takei	42.50	7.96	0.96 (0.91 – 0.98)	2.96	1.70	4.72
Between-day (day 1&2: last jumps)						
My Jump 2	41.23	7.69	0.82 (0.64 - 0.91)	6.40	3.24	8.98
HomeCourt	45.90	7.59	0.80 (0.63 – 0.90)	5.63	3.38	9.37
Takei	42.45	8.20	0.96 (0.92 – 0.98)	3.07	1.65	4.59

SD: standard deviation; Takei: Takei Vertical Jump Meter; ICC: Intraclass correlation coefficient; CV: coefficient of variation; SEM: standard error of measurement; $MDC_{95\%}$: minimal detectable change with 95% confidence level. No significant test-retest differences in each measurement, $p > 0.05$.

Table 2. Pearson Coefficient of My Jump 2, HomeCourt & Takei Vertical Jump Meter

Assessments (n=180)	My Jump 2	HomeCourt	Takei
My Jump 2	1	.85**	.87**
HomeCourt		1	.81**
Takei			1

**. Correlation is significant at the 0.01 level (2-tailed).

Discussion

The present study investigated the test-retest reliability and validity of My Jump 2 and HomeCourt installed on two iPad 6th generation (iOS version 14.4) and a handy Takai jump-testing instrument from Japan, for measuring the CMJ performance in thirty high levels of participation in physical activity. After the data analysis, the investigator found a positive agreement of CMJ height recorded between three measurements, but the Takei is the highly valid and reliable tool in measuring CMJ height in comparison among the measurement tools in two factors (Takei > My Jump 2 > HomeCourt). However, My Jump 2 and HomeCourt still demonstrate good and strong reliability and correlation in the whole tests. Furthermore, the data presented in Pearson's product-moment correlation coefficient presents that the values are very close with other instruments, thus illustrating a strong agreement.

Based on the literature reviews, there were lots of studies that investigated the reliability compared with the My Jump 2 app and force platform (Bogataj et al. 2020, Stanton et al. 2017). This is the first study to compare the test-retest reliability of My Jump 2, HomCourt and the Takei and without any gold standard platform or contact mat. Although force platform or contact mat can provide a valid data to There are different researchers were selected My Jump 2 as one of the measurement tools to assess the test-retest reliability on their research field, to measure the jump height in different target groups. Regarding to previous studies, Bogataj's research team in 2020, they were investigated two studies about the concurrent validity and reliability of My Jump 2 on an iPhone X to compare with the OptoJump device for measuring different jumping technique (Squad Jump, CMJ, CMJ with swing arm) in primary school students' level (CMJ: ICC = 0.96; 95% CI = 0.93 - 0.97) and recreationally

active male and female adults (Male: ICC = 0.96; 95% CI = 0.93 - 0.97; Female: ICC = 0.97; 95% CI = 0.93 - 0.98). It was found that My Jump 2 is a highly reliable measurement tool to measure the jumping performance. Another study from Cruvinel-Cabral's research team in 2018, they were examined the reliability and validity of the My Jump app for measuring CMJ of the elderly. It also displayed a high reliable result compared with the contact mat (ICC = 0.95). The ICC values and the range of 95% CI level of this current study to compare with previous studies, it was slightly lower than previous studies (within-day: 0.85, 95% CI: 0.72 - 0.93; between-day: 0.82, 95% CI: 0.64 - 0.91).

HomeCourt has a good partnership with NBA and contributed the basketball skills training and test on the apps. It provided different basketball skill training, such as shooting and game speed. The agility skills level is also available to measure on the app, such as CMJ. But there is no previous study to investigate the reliability and validity of HomeCourt. This is the first study to investigate the test-retest reliability of HomeCourt for measuring the CMJ performance. Based on the investigation results, the ICC values of HomeCourt still demonstrated a good test-retest reliability. However, HomeCourt has the lowest ICC values (within-day: 0.74; between-day: 0.80) and wider range of 95% CI (within-day: 0.41 - 0.88; between-day: 0.63 - 0.90) compared with My Jump 2 and the Takei. Therefore, when the user chooses an assessment to measure the CMJ performance, HomeCourt might not be the most reliable assessment compared with My Jump 2 and the Takei.

This is the first study to investigate the test-retest reliability of the Takei for measuring CMJ performance. In research from Ramírez-Vélez et al. (2015) have investigated the reliability of the Takei 5415 JUMP-DF DIGITAL VERTICAL

measurement tool for measuring the vertical jump, and the systematic error of 0.217% was found. In previous research, another model from the Takei Scientific Instrument Co., Ltd was used to measure the jump height but not the model was used in current study. Thus, the Takei Vertical Jump Meter has never been investigated for test-retest reliability in the research. In current study, it found that the Takei performed excellent test-retest reliability in both within-day (ICC = 0.96; 95% CI = 0.91 - 0.98) and between-day (ICC = 0.96; 95% CI = 0.92 - 0.98) when measured the CMJ height. In addition, the CV of Takei was the lowest (within-day: 2.96%; between-day: 3.07%) compared with the other two.

Current study is the first study to evaluate the agreement of three assessments. In this study and in the study by Bogataj et al (2020), both studies were evaluated for concurrent validity by Pearson's product-moment correlation coefficient. Bogataj et al (2020) examined the concurrent validity of My Jump 2 app for measuring CMJ in primary school, the strong correlation (r = 0.97) was observed between My Jump 2 and OctoJump device. Similar study investigated by Bogataj et al (2020) for measuring CMJ performance in active adults, it also obtained the strong correlation between My Jump 2 and OptoJump in both active male (r = 0.95 – 0.98) and female (r = 0.94 – 0.97). This is the first study to evaluate the concurrent validity of HomeCourt and the Takei. However, both measurement tools demonstrated positive correlation (r = 0.81 – 0.87).

The present study is the first study that examined the minimal detectable change of each measurement tool. According to the previous study, it only found that MDC evaluated the discrete kinematic parameters in the treadmill running (Bramah et al.,

2021). From the literature review, many related studies only reveal the ICC values of My Jump 2 or other jump height measurement tools but no evaluation on the MDC of each assessment. The MDC is calculating the minimal amount of change which measurement error is accepted to happen. Based on present study, the MDC was calculated by using the between-day results. The Takei performed the lowest SEM values (1.67 cm) and smallest MDC (4.59 cm), which means that the real improvement will be verified if the subject can jump more than 4.59 cm on the Takei. However, the HomeCourt requires the largest change to show the real improvement (MDC = 9.37 cm). It might be a challenge for the participant to have over 9 cm improvement. My Jump 2 also requires 8.98 cm MDC to show the real improvement.

Based on the results, the Takei is the most valid and reliable tool among other measurement tools. From previous studies, My Jump 2 performed the strongest reliable and valid mobile application (ICC > 0.9) when compared with the force plate, but the ICC values in the present study were 0.82 to 0.85. The key limitation of this study was that it did not apply any valid force plate or contact mat in measuring CMJ in various populations, to compare the validity with My Jump 2, HomeCourt and the Takei. But, it is appropriate to analyze the test-retest reliability and validity of those two remote assessments because those are user-friendly and convenient tools that the public can install on their mobile phone.

Additionally, another limitation that HomeCourt is only available to download from the Apple App Store, while people who are using an Android system mobile device are not able to use it. But My Jump 2 is available to download on both Apple and Android system mobile devices, it shows that My Jump 2 is easily accessible.

Many prior studies have used an iPhone with a 240 Hz high speed camera to record the jumping movement on My Jump 2 (Bogataj et al., 2020; Cruvinel-Cabral et al., 2018). The present study used an iPad but also with a 240 Hz camera, which could confirm that an iPad with high quality camera also can be used in measuring the CMJ performance on the remote assessments. On the other hand, the previous study from Gallardo-Fuentes et al. (2016) had stated that the lower capturing frequencies or video recording such as 120 Hz device, it could increase the error of identification on the exact frames of take-off and landing. The study was mentioned that the capture frequencies more than 240 Hz would be suggested to use in the further study. As the rapid technological progression in the last few years, the camera with high recording frequency is the essential configuration in smartphones. Which means that it could increase the accuracy of measuring the jump height of the My Jump 2 and HomeCourt.

Furthermore, the operators' experience of selecting the right frame in which the subject exactly performs on the take-off and landing picture might be the possible reason to influence the jump height result of My Jump 2. Incorrection on selecting the exact frames could affect the jump height result. The test operator has responsibility to select the accurate frames. The Takei rubber mat is black color, and My Jump 2 installed on an iPad was settled in the standard angle with the plastic bracket. It was difficult to identify the accurate moment of take-off and landing if the subject wore black shoes. It would suggest the subject wears light color shoes to participate in further scientific study on investigation of the Takei measurement.

In addition, the present study invited thirty high levels of participation in physical activity which showed a narrow sample size. Thus, participants with

different levels of physical activity should be recruited in further study to broaden the sample size, such as recreationally active participants. The participants' ages of current study were from 23.03 ± 1.67 years old, the larger sample size with different age ranges should be considered in the further study.

Remote assessment not only benefits to sports field, but also can contribute into local primary and secondary school in Physical Education lesson. The STEM education is developing in Hong Kong local school comprehensively. Remote assessment could be the one of the themes in PE lessons. Students can download the My Jump 2 or HomeCourt on their mobile device, and teacher could instruct the skills training and assess their skills level via the apps. It can help to increase the learning motivations of student. More than that, the self-learning behaviors of student could be enhanced. This study showed that which remote assessment is the most valid and reliable tool for measuring the CMJ performance. It could be the information for teacher or public to select the valid and reliable assessment.

Conclusion

The results of this study concluded that the Takei is the most valid, reliable and requires the lowest MDC change of tool for measuring the CMJ performance compared to My Jump 2 and HomeCourt. But, the Takei is not easy to purchase from the community and hard for each athlete to assess. For both remote assessments also displayed the valid and reliable results. However, under the COVID-19 situation, remote assessment such as My Jump 2 and HomeCourt, could bring the convenient and low-cost expense for either professional, amateur or leisure public and athletes to monitor the lower limb explosiveness. To compare My Jump 2 and HomeCourt in the remote assessment aspect, My Jump 2

demonstrated better valid and reliable results and it can suggest promoting for the public, coaches and athletes use.

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Appendix (1) Data Collection Table

Subject/ Tools	Date / Time	My Jump (1)	(2)	(3)	HomeCourt (1)	(2)	(3)	TKJM (1)	(2)	(3)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
Subject/ Tools	Date / Time	My Jump (1)	(2)	(3)	HomeCourt (1)	(2)	(3)	TKJM (1)	(2)	(3)
11										
12										
13										
14										
15										
16										
17										
18										
19										

20										
Subject/ Tools	Date / Time	My Jump (1)	(2)	(3)	HomeCourt (1)	(2)	(3)	TKJM (1)	(2)	(3)
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										