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SHORT REPORT

Validity and Reliability of an Inertial Measurement Unit (BTS G-Walk) for Measurement of Countermovement Jump Height: A pilot-study

Sandeep Kumar[1], Joseph Singh[1], Punam Pradhan[2], Sanjeev Kumar[3], Rohit K. Thapa[4]

[1]Department of Sports Biomechanics, Lakshmibai National Institute of Physical Education, Gwalior, India, [2]Department of Physical Education & Sports Sciences (Faculty of Inter-Disciplinary & Applied Sciences, University of Delhi), New Delhi, India, [3]Department of Physical Education, Central University of Punjab, Bathinda, India, [4]School of Physical Education and Sports, Rashtriya Raksha University, Gandhinagar, India

Abstract

This pilot-study aimed to analyse the validity and reliability of an inertial measurement unit (IMU; BTS G-walk) for measuring the countermovement jump (CMJ) height. Sixteen collegiate male students (age: 19.1 ± 1.4 years; height: 172.7 ± 5.2 cm, body mass: 64.1 ± 6.7 kg) participated in the study. Three trials were conducted for CMJ with the intent of achieving maximal height. The CMJs were concurrently assessed with the IMU and My Jump 2 application. The intercorrelation coefficient (ICC), Pearson correlation (r), and paired t test were used to assess validity. In addition, the ICC, Cronbach alpha (α), and coefficient of variation (CV) were used to assess within-session reliability. The ICC between both devices for measurement of jump height was excellent (ICC = 0.96 [0.90 – 0.99]) with large correlation (r = 0.973). Paired t test showed no difference between both measurement devices. Furthermore, within-session ICC for both devices were good and excellent (ICC = 0.92 [0.82 – 0.97] for IMU; ICC = 0.97 [0.92 – 0.99] for My jump application) and reported acceptable CV (<10%). In conclusion the findings of current study suggest that IMU (BTS G-walk) is a valid and reliable tool for assessment of CMJ height.

Keywords: *plyometric exercise, exercise test, exercise, human activities, athletic performance*

Introduction

Ability to leap vertically is one of the most prevalent fundamental motor skills among human. Indeed, in variety of sports (e.g., volleyball, basketball) having the ability to jump higher (e.g., compared to an opponent) may be advantageous. The vertical jumping ability is often assessed using the countermovement jump (CMJ) test, where the individual uses the stretch-shortening cycle action (i.e., eccentric, amortization and concentric phases). Therefore, practitioners who consider developing athletes' vertical jumping ability to be a key goal, frequently gauge sports performance and physical condition by measuring vertical jumps using the CMJ test (Claudino et al., 2017). Indeed, the CMJ is considered as an important indicator of athletic performance and is been included in assessments of studies that incorporate plyometric jump training, complex training, resistance training etc. (Ramirez-Campillo et al., 2022; Thapa et al., 2021) and across different population (e.g., soccer, swimmers, physically active adults) (Kumar et al., 2023; Ojeda-Aravena et al., 2023; Phukan et al., 2021; Thapa et al., 2022; Thapa et al., 2019).

The CMJ height can be assessed with myriad technologies that are validated and reliable (e.g., contact mat, force platform, software [e.g., MyJump app]) (Balsalobre-Fernández et al., 2014; McHugh, 2018). One such technology is the inertial sensors that are built into inertial measurement unit (IMU), which are multi-sensory devices (i.e., gyroscope, accelerometer, magnetometer) and can be used to aggregate acquired data to measure motion precisely (Andrenacci, 2021). These sensors use the law of inertia to measure angular velocities or linear accelerations and therefore can be used to estimate jump height during CMJ. The BTS Bioengineering corporation manufactures an IMU that also measures the jump height during the CMJ task. However, the validity and reliability of this IMU for CMJ jump height estimation has not been established previously. Therefore, the aim of the present study was to analyse the validity and reliability of

Correspondence:

Rohit K. Thapa, Ph.D.
School of Physical Education and Sports, Rashtriya Raksha University, Gandhinagar 382305, India.
Email: rohitthapa04@gmail.com / rohitkumar.thapa@rru.ac.in
Tel no.: +91 9678324029

BTS G-walk device for measuring the CMJ height. The authors hypothesised that the BTS G-Walk device would be a valid and reliable instrument to measure CMJ height.

Materials and methods

Participants

A total of 16 male participants (age: 19.1 ± 1.4 yrs, height: 172.7 ± 5.2 cm, body mass: 64.1 ± 6.7 kg) were selected for the study. The participants were all healthy physical education students of the university. To be included in the study, the participants had to 1) be free from any lower limb injury in past three months; 2) be able to execute the CMJ with correct form (including landing technique); 3) be able to complete the familiarization and testing sessions. The participants were informed about the procedure of the study and related risk associated during the study. Thereafter, informed consent forms were signed by the participants and/or parents in case participant was minor. The study was approved by internal review board of the university and was conducted following the Helsinki's Declaration.

Procedure

Prior to the commencement of the study, three familiarization sessions were conducted for the CMJ. The anthropometric data were collected during this familiarization sessions. The CMJ test was conducted inside a laboratory. The participants underwent a warm-up protocol of ~10 minutes including running at self-selected speed, dynamic stretching of lower limb muscles, and CMJs. Thereafter, each participant performed three CMJs with the intent of achieving maximal height. Participants were instructed to jump maximally following a countermovement with a self-selected magnitude of knee flexion. All CMJs were performed with hands placed on the hips. No flexion of the legs was allowed during the flight time. The trials deviating from the guidelines of the CMJ were rejected and a new trial was conducted. The jump height was measured concurrently with BTS G-walk and My Jump 2 application. The My Jump 2 is a validated (jump height: r = 0.99) (Balsalobre-Fernández et al., 2014; Wee et al., 2018) IOS application and was installed on an iPhone 13 pro (Apple Inc., California, USA) with a 240-Hz high-speed camera at a quality of 720 p. The camera was directed as low as possible facing each participant in the frontal plane ~2 m away to best record jump performance.

Statistical analysis

Descriptive characteristics of the studied population are reported as mean and standard deviations. Normality of the data was tested using the Shapiro-Wilk test. To establish concurrent validity, interclass correlation coefficient (ICC; two-way random single measures [absolute agreement]), Pearson correlation coefficient, and paired t-test were used. In addition, for reliability analysis ICC, Cronbach's α, and coefficient of variation (CV) were used. The ICC between trials was interpreted as poor (<0.5), moderate (0.5-0.75), good (0.75-0.9), and excellent (>0.9) reliability based on the lower bound of the 95% confidence interval (CI) (Koo & Li, 2016). The CV represented the typical error of measurements expressed as a percentage of mean and a value <10% was considered acceptable (Cormack et al., 2008). Lastly, to complement the ICC analysis, Band-Altman plots were created, which are known to give a good representation of the agreement between the two instruments (Bland & Altman, 1986). All statistical analyses were conducted using IBM SPSS version 20 (IBM, New York, USA). The CV was calculated using the Microsoft Excel sheet. The level of statistical significance was set at p ≤ 0.05.

Results

Mean, standard deviations, and validity statistics are reported in Table 1. The ICC between BTS G-walk and My Jump app was

Table 1. Statistical analysis for validity

	BTS G-walk	My jump app	ICC (95%CI)	r	Mean difference
	Mean ± standard deviation				
Countermovement Jump height	30.18 ± 4.50	30.38±5.17	0.96 (0.90 – 0.99)	0.973	0.2 ±1.3

Note: ICC (95%CI) – Interclass correlation coefficient with 95 % confidence interval, r - Pearson product moment correlation coefficient

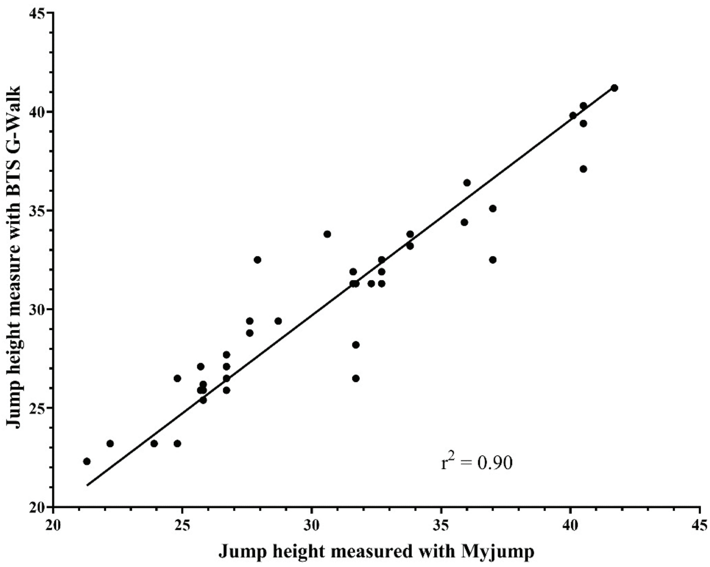

FIGURE 1. Linear regression correlations between jump height obtained from the inertial moment unit (BTS G-Walk) and video-based mobile applications (MyJump 2). Note: The thick solid line represents the regression line and r2 is the coefficient of determination of the regression line.

Table 2. Statistical analysis for within-session reliability

	BTS G walk			My jump app		
	ICC (95%CI)	α	CV	ICC (96%CI)	α	CV
Countermovement Jump height	0.92 (0.82 – 0.97)	0.92	5.57±3.77	0.97 (0.92 – 0.99)	0.97	4.35 ± 2.89

Note: ICC (95%CI) – Interclass correlation coefficient with 95 % confidence interval, α - Cronbach's alpha, CV – coefficient of variation

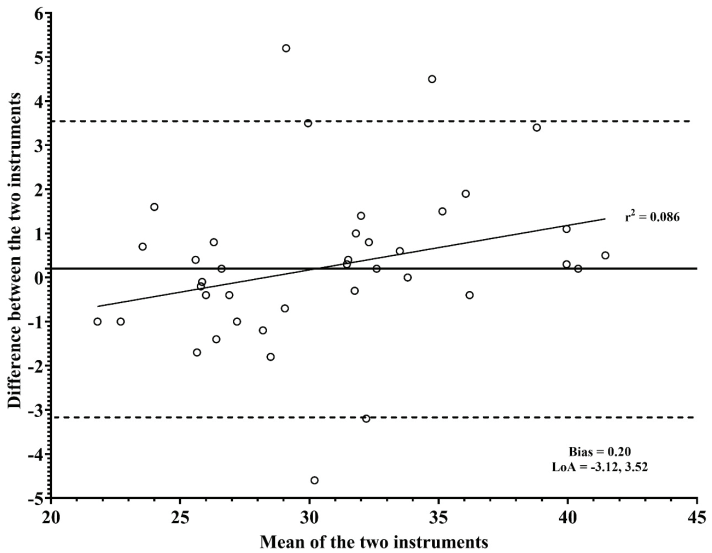

FIGURE 2. Bland-Altman plot for the measurement of jump height using inertial measurement unit (BTS G-walk) and video-based application (MyJump 2 app). The horizontal thick bold line represents the observed bias, and the thin dashed horizontal lines represents ± level of agreement (± 1.96 standard deviation), while the thin line intersecting the thick line is the regression line of the data points. r2: coefficient of determination of the regression line

reported to be excellent. In addition, an almost perfect correlation ($r = 0.973$) was also reported. Paired t-test reported no significant difference between both the instruments ($p = 0.550$) with a mean difference of 0.2. The reliability statistics is presented in Table 2. Within-session ICC for BTS G-walk and My Jump were good and excellent, respectively. Both instruments reported acceptable CV. The scatterplot graphs between the instruments are presented in Figure 1. Similarly, the Bland-Altman plot for the IMU and My Jump application is presented in Figure 2.

Discussion

The aim of this pilot-study was to establish the validity and reliability of an inertial moment sensor - BTS G-walk for measuring the CMJ height in a small sample of 16 participants. Participants were assessed for CMJ height using the BTS G-walk concurrently with a validated video-based analysis software (i.e., My Jump application). The findings of this pilot-study indicate that BTS G-walk may be a valid and reliable instrument to measure the vertical jump of individuals during the CMJ test. Moreover, this pilot-study will serve as a starting point for a further validation in a bigger population sample.

Of note, we observed an excellent correlation between both methods, suggesting that the BTS G-walk can be alternatively used to measure jump height of the individuals. Our findings could be of importance to the scientific community considering that the BTS G-walk is mainly designed for the gait analysis. Therefore, our study supports the multiple use that this device can entail for practitioners, considering its applicability in numerous assessments. However, it should be noted that our study only validates the use of the device for CMJ height assessments. Indeed, in a similar fashion many IMU devices has been validated for different task assessments (Clemente et al., 2022). For example, VERT classic (Mayfonk INC, USA) can be used to record jump counts, consistency of jump, best jump, etc. during the training session or competitive matches. In addition, it can be used to assess CMJ height (Benson et al., 2020). Similarly, another IMU devise Gyko (Microgate, Bolzono, Italy) can be used to analyse walking, running, to do posture analysis, as well as to measure jump heights (Lesinski et al., 2016). Furthermore, global positioning system (Catapult Innovations, Australia) can be used to assess the external training load in addition to measure jump height (Rantalainen et al., 2018).

Although our pilot-study shows that the IMU can measure CMJ height validly, there are few limitations of our study that should be acknowledged. Firstly, the sample size was very low (i.e., 16 participants) considering the pilot nature of the study. However, this study should serve as the basis to validate the IMU with larger population. Secondly, although we used a valid software (i.e., My Jump) to establish the validity of the IMU, using the force platform that is considered 'gold standard' would be an advantage. Thirdly, we could not include female participants in the study. Considering different anthropometric and physiological characteristics between male and female, inclusion of female participants would offer better understanding across population.

Conclusion

In conclusion, the findings of this pilot-study indicate that the BTS G-walk may be a valid instrument to measure jump height in CMJ and that practitioners may use it as a device to track the vertical jump progress of their athletes. Moreover, it may serve as a starting point for further validation study in a bigger population sample.

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Conflict of interest
All authors declare that they do not have any conflict of interest regarding the conduct of this study.

Availability of data and material
All data generated or analyzed during this study will be/are included in the published article as Table(s) and Figure(s). Any other data requirement can be directed to the corresponding author upon reasonable request.

Author's contribution
Sandeep Kumar and Rohit K. Thapa conceived the idea and designed the study. Sandeep Kumar and Punam Pradhan were involved in the data collection procedures. Rohit K. Thapa conducted the formal analysis and interpretation of the data. Sandeep Kumar and Rohit K. Thapa wrote the first draft of the manuscript. Joseph Singh, Punam Pradhan, and Sanjeev Kumar critically revised the draft. All authors read and approved the final version of the manuscript.

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References
Andrenacci, I., Boccaccini, R., Bolzoni, A., Colavolpe, G., Costantino, C., Federico, M., Ugolini, A., & Vannucci, A. (2021). A Comparative Evaluation of Inertial Sensors for Gait and Jump Analysis. *Sensors (Basel)*, *21*(18).

Balsalobre-Fernández, C., Tejero-González, C. M., del Campo-Vecino, J., & Bavaresco, N. (2014). The concurrent validity and reliability of a low-cost, high-speed camera-based method for measuring the flight time of vertical jumps. *J Strength Cond Res*, *28*(2), 528-533. https://doi.org/10.1519/JSC.0b013e318299a52e

Benson, L. C., Tait, T. J., Befus, K., Choi, J., Hillson, C., Stilling, C., Grewal, S., MacDonald, K., Pasanen, K., & Emery, C. A. (2020). Validation of a commercially available inertial measurement unit for recording jump load in youth basketball players. *J Sports Sci*, *38*(8), 928-936. https://doi.org/10.1080/02640414.2020.1737360

Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*, *1*(8476), 307-310.

Claudino, J. G., Cronin, J., Mezêncio, B., McMaster, D. T., McGuigan, M., Tricoli, V., Amadio, A. C., & Serrão, J. C. (2017). The countermovement jump to monitor neuromuscular status: A meta-analysis. *J Sci Med Sport*, *20*(4), 397-402. https://doi.org/10.1016/j.jsams.2016.08.011

Clemente, F., Badicu, G., Hassan, U., Akyildiz, Z., Pino-Ortega, J., Silva, R., & Rico-González, M. (2022). Validity and reliability of inertial measurement units for jump height estimations: a systematic review. *Human Movement*, *23*(4), 1-20.

Cormack, S. J., Newton, R. U., McGuigan, M. R., & Doyle, T. L. (2008). Reliability of measures obtained during single and repeated countermovement jumps. *Int J Sports Physiol Perform*, *3*(2), 131-144. https://doi.org/10.1123/ijspp.3.2.131

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of chiropractic medicine*, *15*(2), 155-163. https://doi.org/10.1016/j.jcm.2016.02.012

Kumar, G., Pandey, V., Thapa, R. K., Weldon, A., Granacher, U., & Ramirez-Campillo, R. (2023). Effects of Exercise Frequency with Complex Contrast Training on Measures of Physical Fitness in Active Adult Males. *Sports (Basel)*, *11*(1). https://doi.org/10.3390/sports11010011

Lesinski, M., Muehlbauer, T., & Granacher, U. (2016). Concurrent validity of the Gyko inertial sensor system for the assessment of vertical jump height in female sub-elite youth soccer players. *BMC Sports Sci Med Rehabil*, *8*, 35. https://doi.org/10.1186/s13102-016-0061-x

McHugh, M. P., Clifford, T., Abbott, W., Kwiecien, S. Y., Kremenic, I. J., DeVita, J. J., & Howatson, G. (2018). Countermovement Jump Recovery in Professional Soccer Players Using an Inertial Sensor. *International journal of sports physiology and performance*, 1-23.

Ojeda-Aravena, A., Herrera-Valenzuela, T., Valdés-Badilla, P., Báez-San Martín, E., Thapa, R. K., & Ramirez-Campillo, R. (2023). A Systematic Review with Meta-Analysis on the Effects of Plyometric-Jump Training on the Physical Fitness of Combat Sport Athletes. *Sports (Basel)*, *11*(2). https://doi.org/10.3390/sports11020033

Phukan, M. I., Thapa, R. K., Kumar, G., Bishop, C., Chaabene, H., & Ramirez-Campillo, R. (2021). Inter-Limb Jump Asymmetries and Their Association with Sport-Specific Performance in Young Male and Female Swimmers. *Int J Environ Res Public Health*, *18*(14). https://doi.org/10.3390/ijerph18147324

Ramirez-Campillo, R., Perez-Castilla, A., Thapa, R. K., Afonso, J., Clemente, F. M., Colado, J. C., de Villarreal, E. S., & Chaabene, H. (2022). Effects of Plyometric Jump Training on Measures of Physical Fitness and Sport-Specific Performance of Water Sports Athletes: A Systematic Review with Meta-analysis. *Sports Med Open*, *8*(1), 108. https://doi.org/10.1186/s40798-022-00502-2

Rantalainen, T., Gastin, P. B., Spangler, R., & Wundersitz, D. (2018). Concurrent validity and reliability of torso-worn inertial measurement unit for jump power and height estimation. *J Sports Sci*, *36*(17), 1937-1942. https://doi.org/10.1080/02640414.2018.1426974

Thapa, R., Clemente, F., Moran, J., Garcia-Pinillos, F., T. Scanlan, A., & Ramirez-Campillo, R. (2022). Warm-up optimization in amateur male soccer players: A comparison of small-sided games and traditional warm-up routines on physical fitness qualities [journal article]. *Biology of Sport*, 321-329. https://doi.org/10.5114/biolsport.2023.114286

Thapa, R. K., Kumar, A., Sharma, D., Rawat, J. S., & Narvariya, P. (2019). Lower limb muscle activation during instep kick from different approach angles and relationship of squat jumpwith 10-m sphnt, 30-m sprint, static balance, change of direction speed and ball velocity among soccer players. *Journal of Physical Education and Sport*, *19*, 2264-2272.

Thapa, R. K., Lum, D., Moran, J., & Ramirez-Campillo, R. (2021). Effects of Complex Training on Sprint, Jump, and Change of Direction Ability of Soccer Players: A Systematic Review and Meta-Analysis. *Front Psychol*, *11*, 627869. https://doi.org/10.3389/fpsyg.2020.627869

Wee, J. F., Lum, D., Lee, M., Roman, Q., Ee, I., & Suppiah, H. T. (2018). Validity and reliability of portable gym devices and an iPhone app to measure vertical jump performance. *Sport Performance & Science Reports*, *44*(v2), 1-5.