

Inter-device reliability of wearable technology for quantifying jump height in collegiate athletes

AUTHORS: Brett S. Nickerson¹, Noel F. Medrano¹, Gabriel L. Perez¹, Samantha V. Narvaez¹, Joshua Carrillo¹, Misael Duque¹

¹ College of Nursing and Health Sciences, Texas A&M International University, Laredo, TX, USA

ABSTRACT: The purpose of this study was to evaluate the inter-device reliability of three VERT devices (Mayfonk Athletic, Florida, USA) when worn on the waist (W), left-hip (LH), and right-hip (RH) during single- and double-leg counter movement jumps (CMJ) in collegiate athletes. Thirty-two female and twenty-eight male NCAA Division II athletes (n = 60) participated in the present study. Jump height (JH) values for double-leg CMJs were analyzed by each device using a one-way repeated measures ANOVA whereas a 2 (jump leg) x 3 (wear location) repeated measures ANOVA was employed to evaluate single-leg CMJs. Reliability of the VERT devices were based upon intraclass correlation coefficients (ICC). Double-leg CMJs revealed an excellent ICC between all three VERT devices (ICC = 0.969). However, JH for RH and LH (45.69 ± 9.84 and 45.82 ± 10.45 cm, respectively) were on average lower than W (50.44 ± 12.37cm; both p < 0.001). The ICCs were excellent for right- and left-leg CMJs (ICC = 0.939 and 0.941, respectively). However, an interaction was observed (p < 0.001). No differences existed for left- or right-leg when VERT was worn on the waist. However, JH was higher when VERT devices were worn on the opposite hip of the jump leg (i.e., LH>RH for right-leg CMJs; RH>LH for left-leg CMJs; all p < 0.001). Results suggest that LH and RH are interchangeable for double-leg CMJs, but not with waist despite excellent reliability. In addition, all wear locations provided excellent ICCs for single-leg CMJs. However, waist provides more consistent JH values for right- and left-leg CMJs while RH and LH show more variability.

CITATION: Nickerson BS, Medrano NF, Perez GL et al. Inter-device reliability of wearable technology for quantifying jump height in collegiate athletes. *Biol Sport*. 2020;37(4):383–387.

Received: 2020-04-29; Reviewed: 2020-06-01; Re-submitted: 2020-06-11; Accepted: 2020-06-17; Published: 2020-07-05.

Corresponding author:

Brett S. Nickerson

College of Nursing
and Health Sciences

Texas A&M International
University

5201 University Boulevard
Laredo, TX 78041

Phone: 956-326-2696

E-mail: brett.nickerson@tamiu.edu

Key words:

Countermovement Jump
Sports
Performance
Sensors
Measurements

INTRODUCTION

Jump height (JH) is a measurement of interest in various athletic sporting populations [1, 2]. For instance, jumping is important for blocking/spiking in volleyball, rebounding in basketball, heading a soccer ball, etc. As a result, strength and conditioning professionals often measure JH when seeking to evaluate performance of athletes [3]. Various methods can be used to assess JH in laboratory and field settings. For instance, laboratory testing of JH often consists of using a force platform [4, 5]. However, the use of a force platform may not be practical for strength and conditioning professionals who do not have adequate training and experience with this technique and the various software packages used for analysis. Therefore, alternative methods (e.g., Vertec, smartphone applications, etc.) are often employed to assess JH in collegiate athletes [6, 7].

More accurate JH measurements have become easier to obtain due to improvements in technology. For instance, the agreement of smartphone applications such as My Jump with force platforms has previously been evaluated and shown small bias (0.9 cm) and strong correlations ($r > 0.90$) [8, 9]. Despite the emergence of smartphone applications, one limitation of this technique is that it does not allow

quantification of JH during game play or practice. In order to overcome these issues, a device known as VERT (Mayfonk Athletic, Florida, USA) was recently developed, which can be worn by athletes during practice or game play.

VERT can be worn by athletes on the hip (left of right) or around the waist as recommended by the manufacturer [10]. It has previously been found that VERT produces similar mean values and excellent reliability when multiple devices are worn around the waist [11–13]. In contrast, bias between VERT devices (i.e., waist and sock) increases the further away the device is from the center of mass (COM), which indicates that wear location is an important consideration [12]. Research has yet to systematically compare VERT devices across waist and hip wear locations despite both being a recommended wear location by the manufacturer. Evaluating the agreement and reliability of waist and hip placement would be valuable in circumstance where athletes differ on wear location preference.

Another factor that has been of interest in research is the utility of VERT for different jump types commonly completed in volleyball practices and games [11, 14, 15]. For example, previous research

has suggested that VERT is an accurate tool to quantify the volleyball attack and block jump [14]. Earlier findings are limited to volleyball. Further, research has yet to consider the impact that single- and double-leg jumps have when predicting JH with VERT devices. This is important for athletes who have a jump leg preference (double-leg instead of single-leg or vice versa). For these reasons, research needs to systematically evaluate whether the wear location and counter-movement jump (CMJ) type (i.e., single- or double-leg) impacts JH measurements obtained via a VERT device. Therefore, the purpose of this study was to evaluate the inter-device reliability of three VERT devices when worn on the waist (W), left-hip (LH), and right-hip (RH) during single- and double-leg counter movement jumps (CMJ) in collegiate athletes.

MATERIALS AND METHODS

Subjects

Thirty-two female and twenty-eight male NCAA Division II athletes ($n = 60$) who played men's basketball ($n = 9$), baseball ($n = 9$), softball ($n = 14$), women's soccer ($n = 7$), men's soccer ($n = 10$), and volleyball ($n = 10$) participated in the current study. The athletes were aged 18 – 25 years (20 ± 2 years). Standing height ranged from 153.00 to 208.50cm (173.35 ± 11.26 cm) whereas body mass ranged from 49.30 to 108.40kg (75.20 ± 13.46 kg). In order to be eligible for the study, athletes had to meet the following criteria: 1) be at least 18 years old; 2) free from lower body musculoskeletal injuries for at least 3 month prior to testing; and 3) a participant of a NCAA Division II athletic sport. Athletes testing times occurred between 8:00am – 3:00pm in order to accommodate student athletes' schedules. Furthermore, athletes were informed to avoid lower body training sessions at least 48 hours prior to testing. All testing performed in the current study were in accordance with the ethical standards of the Helsinki Declaration. Testing consisted of one visit to the Exercise Physiology Laboratory at Texas A&M International University. Upon arrival, athletes were required to complete a health history questionnaire and provide written informed consent

Testing Procedure

After obtaining consent, athletes went through a battery of warm-up protocols. First, athletes self-selected a pace on a treadmill for 5–minutes and completed a dynamic stretching session afterwards. The dynamic stretches consisted of internal-external hip rotations, cariocas, lateral shuffles, high knees, heel kicks, lunges, and straight leg marches, which is similar to warm-up protocols utilized in athletes in previous sport science research [16, 17]. The athletes were then provided demonstrations by a certified strength and conditioning specialist on how to perform each CMJ with hands on hip in order to ensure proper technique. After instructions, athletes performed 2–3 submaximal CMJs at 50, 70 and 90% of their self-selected maximal effort. Rest times for all CMJs ranged from 30–60 sec to allow for adequate recovery time between jumps. After performing the warm-up CMJ protocol, three separate VERT Wearable Fitness

Monitor devices (Mayfonk Athletic, Florida, USA) were placed at the W, LH, and RH. The VERT contains a 3–axis accelerometer and 3–axis gyroscope that classifies movements as jumps and quantifies vertical displacement of each jump through the use of a proprietary algorithm and sampling frequency [15]. Additional information regarding VERT and calculation of JH via their proprietary algorithm can be found on the manufacturer website (<https://www.myvert.com/gvert>). The LH and RH devices were attached with a holster clip and placed at the superior border of the iliac crest. After properly equipped, athletes were asked to perform three maximal single- (right and left) and double-leg CMJs. The order of jumps were double-leg, right-leg and left-leg while hands were placed on the hips. Lastly, the highest measure for each device and jump type (double- and single-leg) was recorded for analysis.

Statistical Analyses

Mean JH values for double-leg CMJs were analyzed using a one-way repeated measures ANOVA. Further, mean JH values for single-leg CMJ measurements were analyzed using a 2 (jump leg) x 3 (wear location) repeated measures ANOVA. When necessary, *post hoc* analysis were conducted with the Bonferroni correction method. A criterion alpha of $p < 0.05$ was used to determine statistical significance. Effect size (ES) of the differences were determined using Cohen's *d*. Two-way mixed, consistency and 95% confidence intervals (CI), intraclass correlation coefficients (ICC) were conducted to determine the inter-device reliability when assessing JH for double- and single-leg jumps. Statistical analyses were performed using SPSS 26.0 software (SPSS Inc., Chicago, IL, USA). All data are presented as mean \pm standard deviations.

RESULTS

Double-Leg Jump Height Measurements

The RH and LH device placement yielded similar double-leg JH estimates (45.69 ± 9.84 and 45.82 ± 10.45 cm; $p = 0.798$, $ES = 0.01$). However, mean values for RH and LH were on average lower than W (50.44 ± 12.37 cm; both $p < 0.001$, $ES = 0.42$ and 0.40 , respectively). Nonetheless, the ICC was near perfect between all device placement locations (ICC = 0.969; 95% CI = 0.953 – 0.981).

Single-Leg Jump Height Measurements

There was an interaction between the single-leg jump and device wear location ($p < 0.001$). When the device was worn on the RH, the JH values for left-leg CMJs were higher than the right-leg CMJs (29.83 ± 6.47 and 26.91 ± 5.52 , respectively; $p < 0.001$, $ES = 0.49$). However, when the device was worn on the LH, the JH values for the right-leg CMJs were higher than the left-leg CMJs (29.46 ± 6.55 and 27.53 ± 5.36 cm, respectively; $p < 0.001$, $ES = 0.32$). When the device was worn on the W, no differences were observed between the right- and left-leg mean JH values (30.81 ± 6.52 and 31.50 ± 6.69 cm, respectively; $p = 0.206$,

ES = 0.10). Despite the differences in JH between device placement locations, the ICC was near perfect for right- (ICC = 0.939; 95% CI = 0.907 – 0.962) and left-leg CMJs (ICC = 0.941; 95% CI = 0.909 – 0.963).

DISCUSSION

The purpose of this study was to evaluate the inter-device reliability of three VERT devices when worn on the waist, LH, and RH during single- and double-leg CMJ in collegiate athletes. The main findings revealed there are systematic discrepancies (mean differences) between RH and LH when compared to W for double-leg CMJs despite excellent reliability. This implies that RH and LH appear to be interchangeable when athletes are performing a double-leg CMJ. Further findings also revealed that all three VERT devices displayed excellent reliability for single-leg CMJs. However, discrepancies appear to exist when evaluating mean JH values and wearing the VERT on the hip (RH and LH) for right- and left-leg CMJs. In contrast, JH values were similar for when evaluating right- and left-leg CMJs. These findings indicate that athletes and sports emphasizing single-leg CMJs should be aware that VERT devices placed on the waist will provide more consistent JH values regardless of which leg is being used for the CMJ. It is worth highlighting that this does not imply waist measurements are valid for single leg-CMJ. Instead, it simply suggests JH values for right- and left-leg may result in more variability when captured with VERT devices worn on the hip.

The current study adds to previous research, which has evaluated the utility of VERT for quantifying jump JH. For example, Charlton et al. [11] revealed that VERT devices worn around the waist systematically overestimate JH by 3.5 to 4.28 cm depending on the jump type athletes perform. Borges et al. [14] added to these findings by demonstrating that attack and block jumps were systematically overestimated by 5.4 and 4.8 cm, respectively, when VERT was compared to Vertec in elite youth volleyball players. The overestimation of VERT when worn in different locations has also been reported in previous research [12]. For example, when worn around the waist and chest, VERT has been found to overestimate JH by 5.5 and 6.6 cm, respectively, when compared to Vertec [12]. Moreover, the overestimation of a VERT device worn around the waist is exacerbated (9.8 cm) when compared to a force platform [12]. These findings suggest the reference method, in conjunction with the wear location, is important to consider when interpreting data analysis and determining the bias of VERT. For example, analysis of a VERT device on a force platform does not ensure results will come out similar when compared to other reference methods such as Vertec or motion capture analysis. Therefore, strength and conditioning professionals should take study results into context, particularly by paying close attention to the reference methods used to complete analysis.

A systematic evaluation of manufacture recommended wear locations has yet to be completed. Furthermore, a majority of research has consisted of evaluation in volleyball players whereas the current

study sought to explore the utility of VERT across various collegiate athletes since this skill-related component applies to various sporting events. The only known study evaluating inter-device reliability employed wear locations that are not recommended by the VERT manufacturer. For instance, Skazalski et al. [12] demonstrated excellent reliability when comparing waist to waist (bias = 0.3cm; ICC = 0.99), waist to chest (bias = 0.9cm; ICC = 0.94), but poor reliability when comparing waist to sock (bias = 4.6cm; ICC = 0.39). The bias between waist and sock for Skazalski et al. [12] is similar to double-leg CMJ mean differences between waist and hip (RH and LH) in the current study. Current recommendations do not include a wear location of the chest, which researchers arbitrarily employed to mimic wearing the device under a sports bra. Furthermore, it is not recommended to wear the VERT around the sock. Accordingly, previous results emphasized the importance of wearing the VERT devices closer to the COM when seeking to enhance reliability, which is consistent with the current study findings, which found excellent ICCs when wearing the VERT in locations close to the COM and in locations currently recommended by the manufacturer (i.e., waist and hip).

This study also uniquely demonstrated that the CMJ type (single- or double-leg) may have an impact on the calculation of JH when wearing the VERT in different locations. These findings are consistent with Charlton et al. [11] who suggested that the bias of VERT depends on the jump types performed by athletes. Although the current study did not employ a reference technique, it is evident that the bias of VERT will not only vary based upon the CMJ jump type (single- or double-leg), but also the wear location. Interestingly, research has shown that VERT tends to overestimate JH when compared to reference techniques when worn on the waist in a similar fashion as the current study [11, 12, 14]. However, these findings contradict previous observations from MacDonald et al. [15] who found that VERT underestimates JH when worn along the lower back in the approximate location of L3 or L4 vertebrae. Accordingly, these discrepancies further emphasize the importance of the current study, which involves being considerate of the wear location recommended by the manufacturer when equipping athletes with the VERT.

The reasons for discrepancies between wear location is a topic of interest. The present study is unable to determine why differences occur when worn on hip or waist for double-leg CMJs and between hip placement (RH and LH) for single-leg CMJs. Nonetheless, reasons for similarities of RH and LH when performing double-leg CMJs is likely because both devices have an equal distance from the COM. Hence, why the RH and LH had similar mean values for JH via the double-leg CMJ, but slightly different values when compared to waist. This is supported in a similar statement by Skazalski et al. [12] who reported bias between waist and other placements (i.e., sock) were not surprising since the VERT is intended to be worn near the COM. The reasons for differences between LH and RH when performing a single-leg CMJ is also worth discussion. For example, when performing a single-leg CMJ jump, one hip is usually higher than the

other. Therefore, this likely explains why the JH values for RH and LH varied based upon the leg (right or left) being used for the CMJ. In contrast, the COM is similar regardless of which leg is performing the single-leg CMJ, which is likely why waist values remained the same. Hence, strength and conditioning professionals seeking to monitor consistent measurements for single-leg CMJs may consider having athletes wear the device on the waist. However, as previously mentioned, this doesn't imply the waist measurement is valid, but simply implies JH values obtained via the VERT may be more consistent across single-leg CMJs (right- and left-leg).

Although the current study adds to previous research, it is not without limitations. For example, the current study did not employ a criterion method such as a force platform or motion capture analysis. As a result, the present study cannot establish, which wear location is valid when performing single- and double-leg jumps. Nonetheless, our findings uniquely identify how wear location and CMJ type can influence the agreement between VERT devices. Another limitation is that authors were unable to evaluate an entire team of athletes within a given sport. Instead, a small number of athletes were obtained from multiple collegiate teams. Accordingly, stratifying athletes by sex and sport would be outside the scope of the current study. Nonetheless, the current study adds to previous literature, which focused solely on volleyball players.

CONCLUSIONS

The current study sought to systematically evaluate whether the CMJ type (single- and double-leg) and wear location of a VERT device is important to consider when working with collegiate athletes across various sports. Previous research has evaluated wearable technology for the quantification of JH [11, 12, 14, 15, 18, 19]. However, the reliability of VERT across different recommended wear locations and across different CMJ types (single- and double-leg) was elusive. Accordingly, the present study was interested in determining whether the inter-device reliability was impacted when having athletes perform single- or double-leg CMJs and wearing VERT devices on the waist and hip. Current study results demonstrate strong reliability, as indicated by the ICCs, between all three wear locations when performing single- and double-leg CMJs. However, discrepancies were observed when evaluating the mean JH values.

The JH values were similar for RH and LH when evaluating double-leg CMJs. However, differences were observed when RH and LH were

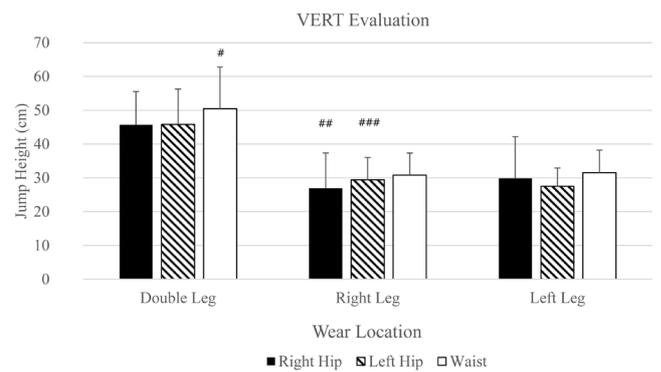


FIG. 1. Jump height values when wearing VERT on waist and hip location for single- and double leg countermovement jumps. Note: #: significantly higher than RH and LH during double-leg CMJ, ##: significantly lower than RH during left-leg CMJ, ###: significantly higher than LH during left-leg CMJ.

compared against waist measurements for the double-leg CMJ. In addition, JH values for waist provided more consistent measurements for right- and left-leg CMJs while RH and LH showed more variability (i.e., LH>RH for right-leg CMJs; RH>LH for left-leg CMJs), which can be visually observed in Figure 1. Current study findings are unable to determine which wear location is more accurate since a criterion method was not utilized. Nonetheless, results of the present study help identify that JH values vary based upon wear location and CMJ type (single- or double-leg). Accordingly, strength and conditioning professionals are encouraged to take these findings into consideration when incorporating VERT devices within an athletic team setting.

Acknowledgments

The authors acknowledge support from the TAMIU Advancing Research and Curriculum Initiative (TAMIU ARC) awarded by the US Department of Education Developing Hispanic-Serving Institutions Program (Award # P031S190304). The authors would also like to extend their thanks to the participants of this study. Lastly, the authors have no conflict of interest to declare in relation to any products used in the current study.

Conflict of Interest

The authors declare no conflict of interest

REFERENCES

- Nikolaidis PT, Gkoudas K, Afonso J, Clemente-Suarez VJ, Knechtle B, Kasabalis S, et al. Who jumps the highest? Anthropometric and physiological correlations of vertical jump in youth elite female volleyball players. *J Sports Med Phys Fitness*. 2017; 57(6):802–10.
- Jensen RL, Ebben WP. Kinetic analysis of complex training rest interval effect on vertical jump performance. *J Strength Cond Res*. 2003;17(2):345–9.
- Nikolaidis PT. Body mass index and body fat percentage are associated with decreased physical fitness in adolescent and adult female volleyball players. *J Res Med Sci*. 2013; 18(1):22–6.
- Aladro Gonzalvo AR, Esparza Yáñez D, Tricás Moreno JM, Lucha López MO. Validation of a force platform clinical for the assessment of vertical jump height. *J Hum Sport Exerc*. 2017; 12(2):367–79.
- Suichomei TJ, Sato K, DeWeese BH, Ebben WP, Stone MH. Potentiation Following Ballistic and Nonballistic Complexes: The Effect of Strength Level. *J Strength Cond Res*. 2016; 30(7):1825–33.

6. Barbosa AG, Gutierrez EV, Keller MW, Martin JL, McArtor JD, Baptista RA, et al. Performance-based correlates to vertical jump height and power values. *Isokinet Exerc Sci.* 2016; 24(2):125–32.
7. Loturco I, Pereira LA, Moraes JE, Kitamura K, Cal Abad CC, Kobal R, et al. Jump-Squat and Half-Squat Exercises: Selective Influences on Speed-Power Performance of Elite Rugby Sevens Players. *PLoS One.* 2017; 12(1):e0170627.
8. Driller M, Tavares F, McMaster D, O'Donnell S. Assessing a smartphone application to measure counter-movement jumps in recreational athletes. *Int J Sports Sci Coach.* 2017; 12(5):661–4.
9. Balsalobre-Fernández C, Glaister M, Lockey RA. The validity and reliability of an iPhone app for measuring vertical jump performance. *J Sports Sci.* 2015; 33(15):1574–9.
10. Mahmoud I, Othman AAA, Abdelrasoul E, Stergiou P, Katz L. The reliability of a real time wearable sensing device to measure vertical jump. *Procedia Engineering.* 2015;112:467–72.
11. Charlton PC, Kenneally-Dabrowski C, Sheppard J, Spratford W. A simple method for quantifying jump loads in volleyball athletes. *J Sci Med Sport.* 2017;20(3):241–5.
12. Skazalski C, Whiteley R, Hansen C, Bahr R. A valid and reliable method to measure jump-specific training and competition load in elite volleyball players. *Scand J Med Sci Sports.* 2018;28(5):1578–85.
13. Manor J, Bunn J, Bohannon RW. Validity and Reliability of Jump Height Measurements Obtained From Nonathletic Populations With the VERT Device. *J Geriatr Phys Ther.* 2020; 43(1):20–3.
14. Borges TO, Moreira A, Bacchi R, Finotti RL, Ramos M, Lopes CR, et al. Validation of the VERT wearable jump monitor device in elite youth volleyball players. *Biol Sport.* 2017; 34(3):239–42.
15. MacDonald K, Bahr R, Baltich J, Whittaker JL, Meeuwisse WH. Validation of an inertial measurement unit for the measurement of jump count and height. *Phys Ther Sport.* 2017;25:15–9.
16. Nickerson BS, Mangine GT, Williams TD, Martinez IA. Effect of cluster set warm-up configurations on sprint performance in collegiate male soccer players. *Appl Physiol Nutr Metab.* 2018; 43(6):626–30.
17. Nickerson BS, Williams TD, Snarr RL, Park KS. Individual and combined effect of inter-repetition rest and elastic bands on jumping potentiation in resistance-trained men. *J Strength Cond Res.* 2018; 33(8):2087–93.
18. Sheppard JM, Gabbett T, Taylor K-L, Dorman J, Lebedew AJ, Borgeaud R. Development of a repeated-effort test for elite men's volleyball. *Int J Sports Physiol Perform.* 2007;2(3):292–304.
19. Jarning JM, Mok K-M, Hansen BH, Bahr R. Application of a tri-axial accelerometer to estimate jump frequency in volleyball. *Sports Biomech.* 2015;14(1):95–105.