

ORIGINAL SCIENTIFIC PAPER

Test-Retest Reliability and Validity of the Velocity-Based Training Device for Measuring Kinetics and Kinematics Variables in Youth Soccer Players

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Abstract

Velocity-based training (VBT) is a popular method for prescribing and monitoring resistance-training load. The aim of this study was to investigate the reliability and validity of the PUSH band for measuring kinetics and kinematics variables during the deadlift exercise at different loads. 16 soccer players (16-18 years) underwent VBT 1 repetition maximum (1RM) protocol over two testing sessions (test-retest). Inertial sensor PUSH Band 2.0 was used for measuring velocity, power, and force during executing hexagonal-bar deadlift at different percentages of 1RM. Test-retest reliability of the VBT-variables was determined by Pearson's correlation coefficients and Bland-Altman plots. Validity was determined by correlating VBT-variables with the Broad jump test (BJ). Average-power, average-, and peak-velocity at 45% 1RM, peak-power at 55% 1RM, average-force and peak-power at 65% 1RM, average- and peak-velocity at 45% 1RM displayed proper test-retest reliability (>50% of the shared variance), which was confirmed by Bland-Altman plots. Average-power, average- and peak-velocity at 45% 1RM displayed the highest correlations with BJ (r=0.78, 0.73, and 0.76, respectively), indicating good validity. VBT-variables at moderate loads were more reliable, which could be explained by the low experience in resistance training of studied players. Variables at low-to-moderate intensity displayed the highest correlation/validity with BJ and could be recommended for the development of this jumping performance in youth players.

Keywords: resistance training, feedback, youth athletes, strength and conditioning, inertial sensors

Introduction

Soccer (football) is one of the most popular sports in the world, and therefore a lot of sports professionals are trying to determine the most effective ways to improve soccer-specific performance. Resistance training or training with external loads is one of the most efficient methods for improving general sports performance and is commonly used in soccer (Barjaste & Mirzaei, 2018). The effectiveness of resistance training largely depends on exercise selection and manipulation of training load (Benson, Docherty, & Brandenburg, 2006). The most common way of determining load is based on prescribing percentages from previously assessed one repetition maximum (1RM), called percentage-based training (PBT). Even though this method has been used for decades, it has some downsides. For example, PBT does not account for athletes' daily strength fluctuations; the level of strength can be decreased due to fatigue or increased due to training adaptation (Eston & Evans, 2009). Simply put, PBT can both overestimate or underestimate optimal daily training load and not provoke intended training adaptations. Therefore, other methods for prescribing training load have recently emerged, with velocity-based training (VBT) being one of the most popular.



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The VBT method utilizes real-time velocity data, which enables objective load adjustments during and between training sessions, avoiding muscle failure (Mann, Ivey, & Sayers, 2015). The main applications of VBT is that it provides immediate feedback on movement velocity to the athlete and coach, and this way load could be adjusted (Weakley et al., 2021). Several researches investigated the differences between PBT and VBT methods. Trained men that were included in the VBT group achieved better levels of maximal strength in the back squat, bench press, overhead press, and deadlift exercise after 6 weeks of resistance training, compared to men in the PBT group during the same period (Dorrell, Smith, & Gee, 2020). Similarly, rugby league players in the VBT group had better improvements in strength levels in back squat and vertical jump performance than the PBT group after 7 weeks of resistance training (Orange, Metcalfe, Robinson, Applegarth, & Liefeith, 2020). Besides previously mentioned evidence of increased effectiveness of the VBT method, technological advancement and increased possibilities of acquiring VBT devices led to increased interest for VBT.

Indeed, numerous commercially available devices exist for the direct measurement of kinetic (power, force) and kinematic (velocity) variables during resistance training exercises. Specifically, the VBT devices include linear position transducers, optoelectronic systems, smartphone applications, and inertial measurement units (IMU) (Courel-Ibáñez et al., 2019). The most popular one is linear position transducer GymAware, which is considered a golden standard VBT device, as it showed the highest reliability and validity (Janicijevic et al., 2021; Thompson, Rogerson, Dorrell, Ruddock, & Barnes, 2020). However, the linear position transducers are more expensive than IMU devices (1800\$ and 400\$, respectively), and commonly more complicated to set up due to cable extensions while IMUs are simply attached to the barbell (Mann et al., 2015). Thus, practitioners and scientists use IMUs, and one of the most popular is PUSH Band.

A study on strength-trained men noted that PUSH Band had high correlation with GymAware velocity recordings during a hexagonal-barbell deadlift, indicating good concurrent validity (Jovanovic & Jukic, 2020), and similar was recorded for bench press exercise (McGrath, Flanagan, O'Donovan, Collins, & Kenny, 2018). Furthermore, PUSH Band displayed appropriate reliability during bench press, back squat, and deadlift exercise (Balsalobre-Fernández, Kuzdub, Poveda-Ortiz, & Campo-Vecino, 2016; Chéry & Ruf, 2019; Lake et al., 2019). However, only few studies investigated metric characteristics of VBT devices for hexagonal-barbell deadlift. Deadlift is a strength-training exercise effective for improving strength and is often used in training programs. Mostly used is deadlift with olympic barbell, but since exercise technique is less demanding, hexagonal barbell becomes increasingly popular (Lockie et al., 2018).

However, there is limited number of studies investigating the reliability and validity of the PUSH Band for hexagonal-barbell deadlift exercise. Precisely, previous studies investigated the validity of the PUSH Band by comparing its values with golden standard devices, and not real-life performance variables (Janicijevic et al., 2021). Also, most of the studies have been conducted on older athletes or strength-trained men, and we found only one on youth athletes (Orange et al., 2019). Therefore, the aims of this study are: (i) to determine the reliability of the PUSH Band for measuring velocity, power and force during hexagonal-barbell deadlift at different loads (percentages of 1RM), and (ii) to determine the validity of the PUSH Band 2.0 by comparing it with jumping performance (horizontal jump) in youth soccer players.

Methods

Participants

Sixteen youth soccer players aged 16-18 years participated in this research. All players practiced soccer for at least eight years and competed at the national rank for juniors. They had at least two years of experience in resistance training and did not have a pause larger than six months before the study initiation. All players were in good health and did not have any injuries during the investigation. Participants were informed about the study's procedures, aims, and purpose and signed informed consent (parents or legal guardians signed the consent for participants under 18 years of age). The study was approved by the Ethical Board of the University of Split, Faculty of Kinesiology, Split, Croatia.

Variables and procedures

This study included anthropometric variables, 1RM assessed with inertial measuring unit used for measuring VBTvariables and Broad jump (BJ).

Anthropometric variables included body height (BH), body mass (BM), and percentage of body fat (% BF), measured by the TANITA measuring scale (model MC780MA, Tokyo, Japan).

VBT-variables included peak and average velocity, relative peak and average power, relative peak and average force, measured during the 1RM protocol using the VBT method. The IMU PUSH Band 2.0 (PUSH Inc., Toronto, ON, Canada) was used for measuring VBT-variables and was placed at the center of the front part of the hexagonal barbell. VBT-variables were recorded at loads at 45, 55, 65, 75, 85, and 95% 1RM. The loads during the VBT assessment of 1RM were chosen based on the previously traditionally assessed 1RM of each player, as suggested previously (Jovanović & Flanagan, 2014). VBTvariables were exported from the PUSH app and were used for further analysis.

The BJ test was used for assessing the horizontal jumping capacity. The participants were asked to jump as far as possible, starting from the marked line on the ground, using an arm swing, and jumping on the standardized measuring mat (ELAN, Begunje, Slovenia). The distance from the start line and the last recorded heel trace of the jump represented the test result (in cm). Players had three attempts, with 30 seconds of rest between the jumps, and the best result (longest jump) for taken for further calculations.

Testing protocol

Players underwent three testing sessions, each separated by 7 days. In the first session, a traditional estimation of 1RM in deadlift was performed. Subjects warmed up with an empty barbell. After that, they performed 6 repetitions with light loads, 3 repetitions with a subsequent heavier load, and a series of one repetition with incrementally increasing load. If the weight was appropriately lifted, players increased the load by 0.5-2.5 kg. The 1RM represented the maximal load (weight) the player managed to lift once. The traditionally estimated 1RM was used for prescribing the load during the 1RM assessment with the VBT method. The second session was the first/initial VBT 1RM assessment and jumping assessment session, while the third session was the second/final VBT 1RM assessment and followed identical protocol and testing order as the second session. The second and third sessions consisted of a warm-up, VBT 1 RM assessment, SJ, and BJ. Players warmed up at a Keiser stationary bicycle (Keiser Corporation, California, USA) for 5 minutes, followed by 2 minutes of agility drills and 5 minutes of mobility protocol. After a warm-up, players conducted BJ test.

After jumps, the incremental 1RM assessment begun. First, players warmed up with an empty barbell for 10 repetitions, performed 6 repetitions at 20% 1RM, 5 repetitions at 30% 1RM. After that, the PUSH Band was attached to the barbell and players began lifting 45% 1RM for 4 repetitions, 55% 1RM for 3 repetitions, 65% 1RM for 2 repetitions, and 75% 1RM, 85% 1RM, 95% 1RM for single repetition, up until they were not able to lift the load. Players had 3 minutes of rest after each increment of load and were instructed to list the load with maximum concentric velocity and ideal posture. Each repetition from 45 to 95% 1RM was recorded using the PUSH Band, and the fastest repetition during each load increment was further analyzed.

Statistical analyses

The normality of the variables was checked with Kolmogorov-Simonov's test for normality. Test-retest reliability of the VBT-variables was determined by Pearson's correlation coefficients.

Additionally, the reliability was checked by Bland-Altman plots by plotting averaged test-retest results against test-retest differences. Validity of the PUSH Band 2.0 was determined by correlating VBT-variables previously found to be appropriately reliable, with the Broad jump test. A p-value of 0.05 was applied, and the program Statistica ver. 13.5 (Tibco Inc., Palo Alto, CA, USA) was used for all calculations.

Results

Test-retest reliability expressed by Pearson's correlation coefficients among VBT-variables at different percentages of 1RM during hexagonal-barbell deadlift is shown in the Table 1. Results evidenced that average power, average and peak velocity at 45% 1RM, peak power at 55% 1RM, average force and peak power at 65% 1RM, average and peak power at 75% 1RM displayed proper test-retest reliability (>50% of the shared variance).

Bland-Altman plots confirmed the reliability of average

Table 1. Test-Retest Reliability Presented by Pearson's Correlation Coefficients between VBT-Variables at Different Percentages

 of 1RM during Hexagonal-Barbell Deadlift

VBT-variables	45% 1RM	55% 1RM	65% 1RM	75% 1RM	85% 1RM	95% 1RM
	Pearson R	Pearson R	Pearson R	Pearson R	Pearson R	Pearson R
Average force	0.35	0.66**	0.82***	0.58*	0.68**	0.57
Peak force	0.63**	0.4	0.6**	0.54*	0.46	0.01
Average power	0.85***	0.62**	0.67**	0.83***	0.64**	0.3
Peak power	0.69**	0.73***	0.7**	0.82***	0.58*	0.64
Average velocity	0.83***	0.39	0.38	0.69**	0.51	0.01
Peak velocity	0.81***	0.61	0.24	0.66**	0.51	0.3

Legend: * p<0.05; ** p<0.01; *** p<0.001

power, average and peak velocity at 45% 1RM, peak power at 55% 1RM (Figure 1), and average force and peak power at 65%









FIGURE 1. Bland-Altman plots for average power (A), peak (B) and average velocity (C) at 45% 1RM, peak power at 55% 1RM (D)

displayed the highest correlations with BJ (r=0.78, 0.73, and 0.76, respectively), indicating proper validity. Variables at

low-to-moderate intensity displayed the highest correlation/ validity with BJ (Table 2).



FIGURE 2. Bland-Altman plots for and average force (A) and peak power (B) at 65% 1RM, average (C) and peak power (D) at 75% 1RM

Table 2. Pearson's correlation coefficients between VBT-variables and Broad jump

	Broad jump			
VBT-variables	Pearson's R	р		
Average power at 45% 1RM	0.78	0.001		
Average velocity at 45% 1RM	0.73	0.001		
Peak velocity at 45% 1RM	0.76	0.001		
Peak power at 55% 1RM	0.70	0.003		
Average force at 65% 1RM	0.64	0.008		
Peak power at 65% 1RM	0.71	0.002		
Average power at 75% 1RM	0.63	0.009		
Peak power at 75% 1RM	0.74	0.001		

Legend: Only those variables where appropriate reliability was found are included in the analysis

Discussion

This study aimed to investigate the reliability and validity of the PUSH band for measuring velocity, power, and force variables during the deadlift exercise at different loads in youth soccer players. The results evidenced two main findings. First, power and force variables are reliable at the low-to-moderate loads (45-75% 1RM) in the deadlift. Second, power and velocity variables at 45% 1RM were highly correlated with broad jump performance, indicating good validity.

Reliability

The study's first finding is that higher reliability was found at moderate percentages of 1RM (moderate loads). Specifically, at percentages higher than 75% 1RM, the test-retest correlation was relatively low (9-to-46% of the shared variance), and therefore reliability was not satisfactory. There are several possible reasons for the lack of reliability at higher loads in studied players. First, the lack of reliability could be explained by the age of the participants and their experience in resistance training.

Namely, the participants in this study were junior soccer players who did not have much experience in training with high loads. The low amount of time dedicated to resistance training in youth athletes is widely known and is mainly attributed to time restrictions due to increased technical sport-specific training (McQuilliam, Clark, Erskine, & Brownlee, 2020). Indeed, our players had an average of 2 years of experience in resistance training, which is most likely not enough to develop the exercise's technique fully. As we included the deadlift exercise in our investigation, this explanation is even more logical since the deadlift exercise is one of the most demanding and complex exercises, and it takes time to accomplish good technique. Hence, the stability of the deadlift execution is not to be expected in youth soccer players.

Therefore, the finding that VBT variables at high loads are not reliable can be explained by an underdeveloped technique to repeat the same motion and movement velocity at high loads. Supportively, a study by Ritti-Dias, Avelar, Salvador and Cyrino (2011) reported that individuals who did not have experience in resistance training displayed variations in maximal strength after consecutive repeated testing of 1RM. Those changes most likely occurred due to familiarization and improved technique and no real changes in maximal strength. This most likely occurred in our players, indicating that measured values do not represent their maximal strength's real state. Consequently, the lack of reliability found at higher loads could be attributed to players' low experience in training with external loads and their insufficiently good technique in deadlift exercise.

The second reason for the lack of reliability at higher loads could be found in the intraindividual variations in exercise execution at high loads, that is, the difficulty to repeatedly perform the movement with sub-maximal or maximal loads in the same way. Similar to our study, a study investigating the reliability of PUSH Band in the deadlift in older participants (22-24 years of age) reported insufficient reliability of velocity and power variables at higher loads (Chéry & Ruf, 2019). The authors explained such findings by the fact that it is challenging to keep the same intend to lift the highest load (close or at 1RM) with maximal velocity. This is especially emphasized in complex exercises/movements such as the deadlift, where individuals try to conduct the lift with the optimum posture to avoid injuries. Thus, it is possible that our players were not able to repeat the same movement at high loads, as it is shown that even older and more experienced individuals do not manage to keep the constant movement at increased loads (Chéry & Ruf, 2019).

Furthermore, it is known that there is a "sticking point" for each individual while trying to lift the maximal load. Briefly, sticking point refers to "the part of the range of motion (ROM) in a resistance exercise in which a disproportionately large increase in the difficulty associated with continuing the lift is experienced" (Kompf & Arandjelović, 2017). Simply put, it is the weakest point of the lift, where individuals tend to slow down while trying to overcome muscular fatigue and failure. It is known that the sticking point is different for each individual and is mainly related to the limb length, torque, and muscle activation (Kompf & Arandjelović, 2016). Therefore, due to large variations in body-built and strength capacities in the studied players, it is reasonable to conclude that each player has a different sticking point which could have affected the reliability of VBT-variables at higher loads in our study.

Validity

Our results showed the association between VBT-variables derived at lower loads and BJ performance. Before explaining this finding, a brief overview of previous studies examining the validity of the PUSH Band will be displayed. Several studies investigated the concurrent validity of the PUSH Band in various strength exercises by comparing it with the "golden standard devices" (i.e., Linear position transducers) and reported mixed findings (Clemente, Akyildiz, Pino-Ortega, & Rico-González, 2021). Precisely, a study by Jovanovic and Jukic (2020) displayed high correlations (r=0.92-0.95) between PUSH Band and GymAware mean and peak velocity recordings for executing hexagonal barbell deadlift in twelve strength-trained men. Contrary, a study investigating the validity of the PUSH Band on 10 strength-trained men comparing it to GymAware, displayed that PUSH Band showed low accuracy in measuring velocity at all percentages of 1RM during the Olympic-bar deadlift (Chéry & Ruf, 2019).

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Conflict of Interest

The authors declare that there is no conflict of interest.

Received: 13 October 2021 | Accepted: 02 December 2021 | Published: 01 February 2022 However, to the best of our knowledge, only one study investigated the validity of the PUSH band in young athletes. Orange et al. (2019) investigated the validity of PUSH Band in youth rugby players by comparing it with the GymAware device. The PUSH Band was valid only for mean power and peak power at 20% 1RM in the back squat (r=0.90-0.91) and mean power at 40% 1RM in the bench press (r=0.89), while it displayed low validity for the velocity variables (Orange et al., 2019). Collectively, PUSH Band displayed appropriate validity mostly for measuring VBT-variables at lower loads (i.e., lower percentages of 1RM).

While previous studies aimed to determine the validity of the PUSH Band by comparing it to other devices, this study investigated the validity by correlating VBT-variables measured by PUSH Band with real-life performances such as jumps. The reason/background for relating the deadlift execution and BJ performance lies in the biomechanical similarity of those two movements. Specifically, the deadlift is a multijoint movement where the most extensive range of motion and the largest muscle activation occurs in the hip joint and then in the lumbar spine, ankle, and knee joint (Brown & Abani, 1985). On the other side, the contribution of the hip joint accounts for 45.9%, for the knee joint 3.9%, and for the ankle joint 50.2% in the BJ performance (Robertson & Fleming, 1987). Thus, we hypothesized that certain VBT-variables derived during the deadlift would be associated with BJ performance.

The results showed the highest associations of power and velocity variables derived at low loads (45% 1RM) with BJ performance (up to 61% of the shared variance), indicating proper validity of these variables. This finding could be observed from the perspective of creating targeted training programs aimed at developing specific performances (i.e., jumps). A well-designed training program aims to develop the wanted performance, which is only possible by knowing exact exercises, modalities, and intensities (i.e., loads) that influence the development of that specific performance (Lesinski, Prieske, & Granacher, 2016). Therefore, according to our results, it could be suggested that in-corporating deadlift exercise with low-to-moderate loads in the training program could provoke the best development and adaptations in jumping capacities in youth soccer players.

Conclusion

Results evidenced that VBT-variables at moderate loads are more reliable, which could be explained by the low resistance-training experience of studied players. Variables at low-to-moderate intensity displayed the highest correlation/validity with horizontal jump.

Therefore, this study has some practical implications. First, deadlift exercise with low-to-moderate loads in the resistance-training program could be used for developing jumping capacities in youth players. Also, PUSH Band is not reliable for measuring VBT-variables at higher loads, meaning that its use should be limited for moderate loads. This research investigated only youth soccer players, and the results should be applicable only for this age-group, therefore, future studies should investigate older players.

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