Reliability and Concurrent Validity of Seven Commercially Available Devices for the Assessment of Movement Velocity at Different Intensities During the Bench Press

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Abstract
Pérez-Castilla, A, Piepoli, A, Delgado-García, G, Garrido-Blanca, G, and García-Ramos, A. Reliability and concurrent validity of seven commercially available devices for the assessment of movement velocity at different intensities during the bench press. J Strength Cond Res 33(5): 1258–1265, 2019—The aim of this study was to compare the reliability and validity of 7 commercially available devices to measure movement velocity during the bench press exercise. Fourteen men completed 2 testing sessions. One-repetition maximum (1RM) in the bench press exercise was determined in the first session. The second testing session consisted of performing 3 repetitions against 5 loads (45, 55, 65, 75, and 85% of 1RM). The mean velocity was simultaneously measured using an optical motion sensing system (Trio-OptiTrack; “gold-standard”) and 7 commercially available devices: 1 linear velocity transducer (T-Force), 2 linear position transducers (Chronojump and Speed4Lift), 1 camera-based optoelectronic system (Velowin), 1 smartphone application (PowerLift), and 2 inertial measurement units (IMUs) (PUSH band and Beast sensor). The devices were ranked from the most to the least reliable as follows: (a) Speed4Lift (coefficient of variation [CV] = 2.61%); (b) Velowin (CV = 3.99%), PowerLift (3.97%), Trio-OptiTrack (CV = 4.04%), T-Force (CV = 4.35%), and Chronojump (CV = 4.53%); (c) PUSH band (CV = 9.34%); and (d) Beast sensor (CV = 35.0%). A practically perfect association between the Trio-OptiTrack system and the different devices was observed (Pearson’s product-moment correlation coefficient [r] range = 0.947–0.995; p < 0.001) with the only exception of the Beast sensor (r = 0.765; p < 0.001). These results suggest that linear velocity/position transducers, camera-based optoelectronic systems, and the smartphone application could be used to obtain accurate velocity measurements for restricted linear movements, whereas the IMUs used in this study were less reliable and valid.

Key Words: linear position transducer, linear velocity transducer, smartphone application, inertial measurement units, velocity-based training, testing

Introduction
Velocí get-based resistance training has gained in popularity over recent years because of the proliferation of different commercially available devices (e.g., linear position transducers, inertial measurement units [IMUs], smartphone applications, etc.) that are supposed to accurately measure movement velocity (3,5). It has been proposed that the monitoring of barbell velocity could be an appropriate alternative to prescribe the training load as compared to the traditional approach that requires the determination of the 1 repetition maximum (1RM) (17,32). The use of movement velocity to prescribe the training load is justified by the strong and linear relationship that has been reported for multiple exercises between movement velocity and the %1RM (13,26,31). In this regard, instead of determining the 1RM through a single maximal lift or by a set of repetitions to failure, the load can be prescribed to match the desired velocity (17,34). Despite the encouraging applications of velocity-based resistance training (6), little research is available comparing the reliability and validity of different commercially available devices used in training and research to monitor movement velocity.

From a scientific standpoint, the three-dimensional (3D) motion capture has been recognized as the “gold-standard” instrument to measure movement velocity (22,36). However, because this technology is not practical or affordable for strength and conditioning professionals, other devices are typically used in practice when implementing the velocity-based resistance training approach. The linear position transducer has been the most used device in scientific research (2,5,10,14). The linear position transducer consists of an isoinertial dynamometer with a cable that is typically attached to the barbell, and it derives velocity from the recorded displacement-time data using the inverse dynamic approach (18). More recently, a linear velocity transducer named “T-Force” (T-Force system; Ergotech, Murcia, Spain) has been made commercially available, which directly provides velocity measurements through the recording of electrical signals that are proportional to the cable’s extension velocity (33). It is reasonable to speculate that the linear velocity transducer could be more precise than linear position transducers because it is known that the successive manipulation of
raw data increases measurement errors (25,30). However, it remains unexplored whether the reliability of velocity outputs significantly differs between linear position and linear velocity transducers, as well as their concurrent validity with respect to the “gold-standard” 3D motion capture.

It should be acknowledged that linear position/velocity transducers are not always practical or affordable. The need to attach the cable to the barbell restricts exercise selection to the ones predominantly performed in a vertical direction (5). Another common drawback of linear position/velocity transducers is their high price (>2,000 US dollars), which may limit their use to laboratory-based or professional sport settings (7,23,24). However, it should be noted that a new linear position transducer named “Speed4Lift” (Speed4Lift, Speed4Lift, Madrid, Spain) has appeared on the market with a considerably lower price (340 US dollars), although there are no available data regarding its reliability and validity. As an alternative to linear position/velocity transducers, wearable technologies are increasingly gaining popularity in the field of strength training and conditioning (3,5,12,28).

One of the wearable devices that have recently appeared on the market is named “Velowin” (Velowin; DeporTeC, Murcia, Spain). Velowin is a camera-based optoelectronic system designed to measure movement velocity by the tracking of an infrared reflective marker placed in the barbell. A high reliability and concurrent validity of the Velowin to measure movement velocity has been reported during the free-weight back squat exercise (12,21). The main advantage of Velowin as compared to linear position/velocity transducers is that it does not require to be attached to the barbell through a cable and, therefore, this would eliminate the risk of cable rupture (21). However, the Velowin cost (≥625 US dollars) and limited portability (e.g., a PC software is needed) could limit its use for many strength and conditioning professionals. Many practitioners can only afford more practical devices such as smartphone applications or IMUs (2,28).

A smartphone application named “PowerLift” has been designed to monitor movement velocity by the manual inspection of a slow motion video recording by the smartphone high-speed camera (4). The high reliability and validity of PowerLift to monitor mean velocity has been confirmed in exercises such as the bench press, full-squat, and hip-thrust (3,4). However, the main limitation of PowerLift is that it does not provide real-time velocity feedback because coaches are required to indicate manually the start and end of the concentric phase. The PUSH band (PUSH band, PUSH, Inc., Toronto, Canada) and Beast sensor (Beast sensor, Beast Technologies Srl., Brescia, Italy), which are composed by the combination of 3-axis accelerometers and 3-axis gyroscopes, are 2 of the IMUs most commonly used in research and practice (3,5). An advantage of IMUs is that they are able to account for the anteroposterior displacement that is frequent during free-weight exercises (28), whereas linear position/velocity transducer cannot distinguish the direction of the cable displacement. However, owing to the discrepancies found between the studies that have evaluated the validity of the PUSH band (3,5,36) and owing to the scarce number of studies that have examined the reliability and validity of the Beast sensor (3), more research is needed to explore the feasibility of both IMU devices.

To address the existing gaps in the literature, this study was designed to provide a comprehensive analysis of different devices (i.e., linear velocity transducer, linear position transducers, camera-based optoelectronic system, smartphone application, and IMUs) that are being used in practice for the measurement of movement velocity during resistance training. Specifically, the objective of this study was to compare the reliability and validity of 7 commercially available devices to measure movement velocity during the bench press exercise. We hypothesized that the devices would be ranked from the most to the least reliable and valid as follows: (a) linear velocity transducer; (b) linear position transducers; (c) camera-based optoelectronic device; (d) smartphone application; and (e) IMUs. The results of this study should provide practical information for strength and conditioning coaches regarding the reliability and concurrent validity of different devices that can be used in practice for the assessment of movement velocity.

Methods

Experimental Approach to the Problem

This study was designed to explore the reliability and concurrent validity of 7 commercially available devices for the measurement of movement velocity. Subjects completed 2 testing sessions separated by 48–72 hours. The 1RM in the bench press exercise was determined in the first testing session. The second testing session consisted of performing 3 repetitions against 5 different loads (45, 55, 65, 75, and 85% of 1RM). The mean velocity of the barbell was measured using an optical motion sensing system (V120: Trio, OptiTrack; NaturalPoint, Inc., Corvallis, OR) that was considered the gold standard in this study (27,38). In addition, the mean velocity was also measured by 7 commercially available devices: 1 linear velocity transducer (T-Force system, Ergotech), 2 linear position transducers (Chronojump; Boscosystem, Barcelona, Spain; and Speed4Lift), 1 camera-based optoelectronic system (Velowin, DeporTeC), 1 smartphone application (PowerLift), and 2 IMUs (PUSH band; PUSH, Inc., and Beast sensor; Beast Technologies Srl.). The 2 repetitions with higher mean velocity recorded by the Trio-OptiTrack at each load were used for calculating intrasession reliability (3,21), whereas only the repetition with the highest mean velocity recorded at each load by the Trio-OptiTrack was used for validity analyses.

Subjects

Fourteen men (mean ± SD: age: 22.9 ± 1.6 years [age range: 20–25 years old]; body height: 1.76 ± 0.06 m; body mass: 76.9 ± 7.8 kg; bench press 1RM: 86.1 ± 11.9 kg) volunteered to participate in this study. Subjects were recruited from a fitness center, and all of them were familiarized with the bench press exercise before the beginning of the study. None of them suffered from physical limitations, health problems, or musculoskeletal injuries that could compromise tested performance. Subjects were instructed to avoid any strenuous exercise 2 days before each testing session. They were informed of the study procedures and signed a written informed consent form before initiating the study. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the University of Granada Institutional Review Board.

Procedures

The first testing session was used for anthropometric measures and to determine the 1RM during the concentric-only bench press exercise following an incremental loading test (11). The standardized warm-up consisted of jogging, self-selected dynamic stretching and joint mobilization exercises, and 1 set of 5 repetitions performed against external load of 17 kg (mass of the unloaded Smith machine barbell) during the bench press exercise. Thereafter, the external load was incremented from 10 to 1 kg until the 1RM load was reached. The average number of loads...