

ACCELEROMETER-BASED INSTANTANEOUS FEEDBACK TECHNOLOGY IS AS EFFECTIVE AS COACH'S SUPERVISION ON THE QUANTITY AND QUALITY OF RESISTANCE TRAINING SESSIONS FOR UNIVERSITY WRESTLING ATHLETES

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ABSTRACT

Background and Objective

We investigated how VBT devices' instantaneous feedback affects resistance training efficiency under different intensities.

Material and Methods

Eight university wrestling athletes were recruited (21 ± 0.42 years) and three separated experiments were conducted under no-supervision (NSUP), coach supervision (CSUP), and instantaneous velocity feedback (VBT) conditions on 10 days apart. Maximal repetition to failure back squat on 65%1RM and 85%1RM was performed on 1080 quantum smith machine.

Results

Repetition and volume were significantly greater in CSUP (Rep: $p=0.034$, Vol: $p=0.020$) and VBT (Rep: $p=0.003$, Vol: $p=0.001$) than NSUP group at 65%1RM, but VBT group only showed statistically greater outcomes at 85%1RM than NSUP (Rep: $p=0.015$, Vol: $p=0.020$). However, total work was only significantly greater in VBT group regardless of intensity, and it showed identically greater at 65%1RM than both NSUP ($p=0.001$) and CSUP groups ($p=0.036$). While peak force remained as no difference between any groups and trials, peak velocity and power was significantly greater in VBT group than NSUP (p_{Vel} 65%1RM: $p=0.018$ and 85%1RM: $p=0.007$, p_{Pow} 65%1RM: $p=0.004$ and 85%1RM: $p=0.006$) and CSUP groups (p_{Vel} 65%1RM: $p=0.008$ and 85%1RM: $p=0.023$, p_{Pow} 65%1RM: $p=0.001$ and 85%1RM: $p=0.015$) regardless of intensity.

Conclusion

The present study, therefore, concluded that the instantaneous feedback from VBT device encouraged wrestling athletes to perform longer and harder than coach's encouragement in the resistance training. This may suggest that velocity-based training effectively assisted resistance training session even if the strength coach or team coach is not available.

Key Words: *auditory feedback; training efficiency; VBT; velocity-based training; visual feedback*

INTRODUCTION

A coach's feedback is important to encourage athlete's motivation and facilitates optimal concentration on the tasks regardless of training types.¹ Elite athletes should have superior muscular functionalities to maximize athletic performance.² Most of the athletes in the competitive environment, therefore, frequently train in the weight training room to improve muscular endurance, strength, and power,³ with the evidence that this type of participation is steadily increasing.⁴ To avoid compromising outcomes, resistance training should be supervised by highly experienced and/or qualified strength and conditioning specialists to appropriately address and focus on the training goals.⁵

It is rare to observe how and where experienced certified strength and conditioning specialists (CSCSs) train groups of elite athletes in their training facility, especially for university teams due to a lack of financial support or an underestimation of their importance. Even if the team has a trainer, they are usually only qualified as a personal trainer, and are rarely certified as an athletic trainer or a CSCS. Accordingly, coaches occasionally supervise the resistance training sessions despite their limited knowledge compared with the CSCSs.⁶ Although technical coaches may not have sufficient knowledge in resistance training, they still play an important role as a very influential motivator during weight training sessions.⁷ However, unless technically training for specific events, most athletes in teams or groups train themselves, so the quality of training is questionable.

In the majority of combat sports like Taekwondo, Wrestling, or Judo, athletes frequently

train as a group in one weight training room at the same time without proper supervision. Without the proper instruction regarding appropriate training loads, intensity set ups, and techniques of weight training, the risk of injury may increase.⁸ In addition, this could possibly minimize training efficiency and effectiveness as athletes rarely lift weights with maximal effort, perform repetitions to failure, or use the ballistic movement, which are critical components of enhancing endurance and power development.⁹ Not only muscular endurance, strength, and power are fundamental physical fitness components that must be properly developed for the wrestling athletes,¹⁰ but multiplane quickness and reactivity are also very important success factors in this event because they must react very rapidly and forcefully against opponent, so their movements should be very fast and precise so as to training.^{11,12} Training modalities should be based on the specificity of the event as the neuromuscular components must be specifically adapted to the imposed demand.¹³ If athletes wish to improve muscular endurance, they must let their physiological system metabolically challenging through the maximum possible repetitions.^{14,15} On the contrary, if rapid and powerful movement is the main concern of the training outcomes, the velocity of muscular contraction should be at least intentionally fast.^{16,17} Even if the actual velocity is slower as the weight goes heavier enough, this intention still effectively recruits higher threshold motor units in the type IIx muscle fibers, hence potentially expects the greater rate of force development.¹⁸ However, the

training outcomes would not be promising, unless proper supervision is kept maintaining.^{19,20}

There are two possible external feedbacks that could increase resistance training quality in terms of motivation and concentration. One would be verbal encouragement from a coach and the other would be an instantaneous real-time feedback from biomechanical measurements devices such as linear position transducers (LT), or accelerometers. The strength and conditioning community have recently been very focused on velocity-based training, commonly referred to as VBT,⁵ which uses accelerometer technology. This allows them to apply science to real-world practical resistance training sessions and instantaneously shows mechanical metrics including force and power, which are based on movement velocity measurements.^{21,22} This device is very popular due to a very competitive cost and high accuracy compared with the LT and force plate.²¹ However, it is still questionable if this technology would enhance an athlete's motivation and concentration and if it would be good enough to replace a supervisor during resistance training sessions. In other words, would this technology be as effective as a coach's supervision and encouragement?

It is normally considered that the coach's encouragement motivates athletes to overcome the fatigue to achieve more repetition and may help athletes to aggressively lift weight so as to increase force and velocity in the resistance sessions⁷; however, there are no studies that have fully investigated how much those external feedback can push athletes toward their maximal muscular capacities, especially in the university wrestling athlete population, who do not often perform resistance training under a coach's supervision. Consequently, this study investigated how VBT devices' instantaneous feedback affects resistance training efficiency under different intensities to determine its applicability in a non-supervisory resistance training setting.

MATERIALS AND METHODS

Experimental approach to the problem

To determine how the coach's encouragement and VBT instantaneous feedback affect the mechanical outcomes of resistance training, we conducted three separate weight training sessions: a control group (without a coach [NSUP]), a coach with verbal encouragement (CSUP), and VBT only. Three resistance training sessions were performed 10 days apart to minimize training effect interferences.¹⁹ The sessions consisted of one set of repetition to failure for squat exercises at 65 and 85% of an individual's 1RM with at least 7 min of rest between sets.²³ No feedbacks were given when train without coach, and subjects were allowed to stop when they felt they cannot lift no more repetition, so all decisions were made by themselves, but they asked to do their best under their normal lifting style. For the CSUP session, although subjects were encouraged to do their best, training style was controlled under the coach's knowledge. However, squat depths were strictly controlled as thigh parallel to the floor by investigator in all sessions.

Subjects

Ten university wrestling team athletes were initially recruited for the study, but only eight completed all experimental sessions. One dropped out due to knee pain and another was dropped in the second session because of upper respiratory infection symptoms which included a high fever and sore throat. All subjects were familiar with the resistance training protocols and did not have any neuromusculoskeletal pain in their ankles, knees, back, or shoulders (Table 1).

All subjects were in their season training phase and they trained 5 days a week, but did not utilize resistance training; therefore, the experiments included only resistance training sessions. All subjects were informed of the purpose of the study and they submitted a consent form. All experimental procedures were performed in

TABLE 1. Subject Characteristics

Variables	Subject (n)	Age (years)	Height (cm)	Weight (kg)	Body fat (%)	1RM (kg)	Training age (years)
Mean±SE	8	21.0±0.42	170.69±4.04	78.43±7.33	16.9±3.94	135.00±05.90	7.25±0.56

Mean, average; SE, standard error.

accordance with the guidelines of the Institutional Review Board of Dong-A University.

Procedures

Standardized warm-up sessions consisted of two components: a 5-min dynamic stretch and mobility drills including deep squats, side lunges, front lunges with their contralateral arm reaching to the ceiling, and then five deep squat repetitions using a 10-kg barbell were performed prior to every experimental session which included maximum squat strength testing. Subjects were then asked to rest at least 5 min before beginning the actual testing.

Lower body strength assessment

The first experiment was one-repetition maximum load finding session. The load-velocity profiling method^{5,24} was applied to estimate subjects 1RM weight using a 1080 quantum smith machine (1080 Quantum synchro, 1080 Motion AB, Stockholm, Sweden). Push-band accelerometer (PUSH Inc., Toronto, Canada) attached on the bar and I-Pad application automatically calculated and showed an estimated 1RM once the subject had completed five-step load increment testing. Subject then asked to lift the suggested 1RM weight. If the subject failed to lift the suggested 1RM load, then they were allowed to rest at least 3 min before trying another attempt, but the weight was adjusted to accommodate the athlete's ability. The same rest time was given if the lifting was successful and repeated until achieving the fail to lift endpoint.

Experimental trials

The second experiment was conducted 3 days after the 1RM testing session. It consisted of one set of repetition to failure trials at 65 and 85% of

an individual's 1RM, with at least 7 min of recovery time given to the subject before the next set.²³ No feedback was given to subjects during NSUP, and athletes were allowed to stop when they felt they could not complete another repetition, though they were asked to do their best using their normal lifting style velocity and tempo. No more than 2 s resting time was allowed at the top of the lift and the depth was strictly restricted to only reach their thighs while parallel to the floor to minimize any displacement variabilities during the tests.

The third experiment (CSUP) was conducted 10 days later at exactly the same time of the day of the other experiments to minimize any biological disturbances due to circadian rhythms,²⁵ and the coach used verbal encouragement to optimize the subjects' performances. Any physical contact and assistance were prohibited. Exercise intensity, rest duration, and sequence were all identical to the second experiment.

The last session (VBT) provided velocity scores on an I-Pad screen set in front of the subject while they were lifting weights. The investigator briefly explained what the numbers meant showing on the I-Pad. While lifting the weight, each repetition velocities was instantaneously indicated on the monitor including a high tone ring sound with a green flashing light. However, if the repetition velocity is slower than the subject's 1RM velocity, it showed the red flashlight with low tone beep sound. In addition, as subjects recognized one's own 1RM velocity, it was easy for them to be aware of whether they were truly pushing themselves to the real maximal threshold. The subjects were asked to focus on the numbers and encouraged to maximize their velocity score during every repetition. No feedback or encouragement from

investigators and colleagues were given during the test and resting periods.

A Push-band accelerometer²⁶ was attached on the bar and tightly mounted with double-sided tape. All data were automatically saved at a sampling frequency of 200 Hz and transmitted via Bluetooth to the PUSH application software (Version 1.126, Toronto, Canada) on the I-Pad, then downloaded as comma separated value (CSV) files from the PUSH web portal (<https://app.pushstrength.com>) to a computer using the Google Chrome browser. Training files were then converted to a Microsoft Excel file format to further analyze how the coach's encouragement and VBT technology affect the resistance training session kinematic outcomes.

Statistical analysis

All values are presented as a mean with a standard error of estimate (SE). Data were analyzed with a two-way analysis of variance (ANOVA) using repeated measurements. The least significant difference (LSD) test was conducted when a significant *F*-ratio was achieved. Statistical significance was considered as $p < 0.05$.

RESULTS

Quantity analysis

Repetition and volume were collected as a quantity factor. Although the total workload may be considered as a quality factor as it incorporates dominant factors including force and distance,

it is categorized as a quantity factor group because it is the sum of all values. Both repetition and volume significantly increased in the CSUP and VBT groups compared with the NSUP group at 65% 1RM (reps: 19.50 ± 2.44 reps/set, 23.38 ± 2.81 reps/set, 11.88 ± 1.74 reps/set, respectively) (volume: 1678 ± 207.53 kg/set, 2061.88 ± 222.36 kg/set, 992.25 ± 146.45 kg/set, respectively, $p < 0.05$ for both), but the statistical difference was far greater in the VBT group compared with the CSUP group (reps: $p = 0.003$ vs. $p = 0.034$, volume: $p = 0.001$ vs. $p = 0.020$). In the 85% 1RM trial, a statistical difference for repetition and volume was only observed when the VBT group was compared with the NSUP group (reps: 8.50 ± 1.41 reps/set vs. 4.50 ± 0.71 reps/set, volume: 972.75 ± 163.95 kg/set vs. 527 ± 92.19 kg/set, $p < 0.05$, respectively, for both sets), as shown in Figures 1a and 1b.

The total workload is presented in Figure 1c, and clearly shows that the VBT group ($26,525 \pm 2378.88$ J) worked significantly harder than either the NSUP (11761.67 ± 1639.75 J) or the CSUP group (18372.68 ± 3405.72 J), at the 65% trial ($p < 0.05$), but in the 85% 1RM trial, a statistical difference was only observed between the VBT and NSUP groups (10444.04 ± 1706.31 J vs. 5128.55 ± 925.82 J, respectively, $p < 0.05$).

Quality analysis

Power, force, and velocity values were considered quality factors in the present study.

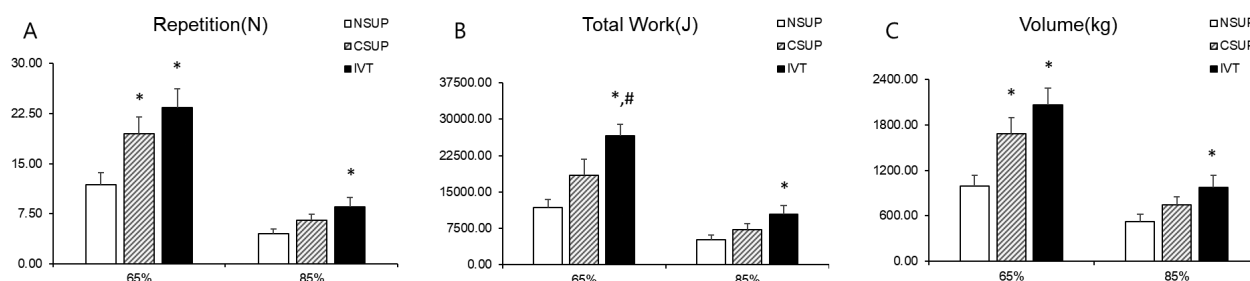


FIG. 1 Quantity factors comparison under 65 and 85% 1RM back squat repetition to failure between NSUP, CSUP, and VBT groups.

NSUP, no-supervision; CSUP, coach supervision; VBT, instantaneous velocity feedback. *Statistical difference compared with NSUP; #statistical difference compared with CSUP, $p < 0.05$.

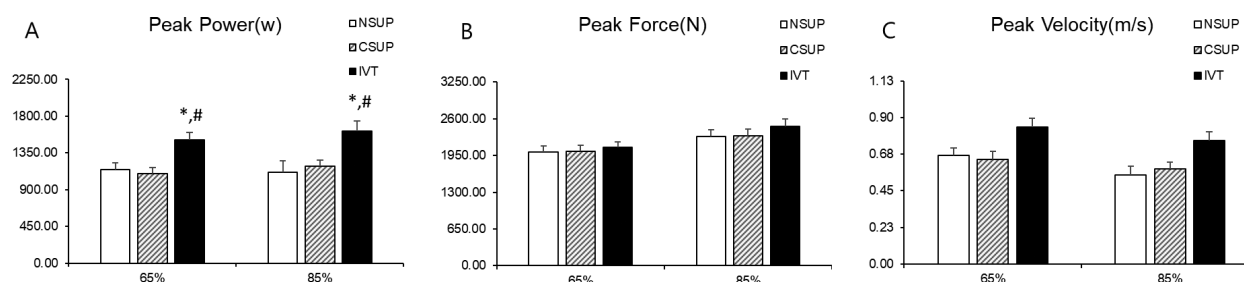


FIG. 2 Quality factors comparison under 65% and 85% 1RM back squat repetition to failure between NSUP, CSUP, and VBT groups.

NSUP, no-supervision; CSUP, coach supervision; VBT, instantaneous velocity feedback. *Statistical difference compared to NSUP; #statistical difference compared with CSUP, $p < 0.05$.

Peak power (Figure 2a) significantly increased only in the VBT group during both the 65% 1RM (1511.28 ± 86.07 W [VBT] vs. 1143.76 ± 82.33 W [NSUP] and 1016.92 ± 70.89 W [CSUP]) and the 85% 1RM trials (1617.91 ± 121 W [VBT] vs. 1112.4 ± 139.91 W [NSUP], and 1183.67 ± 77.26 W [CSUP], $p < 0.05$). No statistical differences were found in peak force (Figure 2b) in any group or trial, but there was a tendency to increase the values going from NSUP to CSUP to VBT.

Lastly, peak velocity showed exactly the same patterns shown in Figure 2c, where the VBT group identically increased the values compared with the NSUP and CSUP groups during the 65% 1RM (0.84 ± 0.05 m/s (VBT), 0.67 ± 0.05 m/s (NSUP), and 0.64 ± 0.05 m/s (CSUP), $p < 0.05$) and the 85% 1RM trials (0.76 ± 0.05 m/s (VBT), 0.55 ± 0.05 m/s (NSUP), and 0.59 ± 0.04 m/s (CSUP), $p < 0.05$).

DISCUSSION

The present study clearly demonstrated that the coach's supervision (CSUP group) and an instantaneous feedback from accelerometer technology (VBT group) enhance training efficiency in the number of repetitions, training volume, and the total workload compared with the unsupervised (NSUP) group. However, the magnitude of the workload increment demonstrated that the quantity and the quality were enhanced in the VBT

group because the workload equation includes force and distance. In fact, a direct measurement of peak power and peak velocity showed significantly higher values in the VBT group compared with either the NSUP group or the CSUP group. Therefore, we concluded that VBT is as effective as a coach's supervision in terms of resistance training quantity, and far more effective in terms of quality for certain variables including peak power and peak velocity.

The present study found a significantly increased number of repetitions and volume in the CSUP and VBT groups compared with the NSUP group during the 65% 1RM squat (NSUP: 11.88 ± 1.74 , CSUP: 19.50 ± 2.44 , VBT: 23.38 ± 2.82 , respectively) and the 85% 1RM trials (NSUP: 4.50 ± 0.71 , CSUP: 6.50 ± 0.95 , VBT: 8.50 ± 1.41 , respectively). This increment may indicate how direct supervision affects improvement in resistance training quantity, which may potentially contribute to muscular endurance, hypertrophy, and strength gain because the cross-sectional area of muscle will be increased after metabolic acidosis through higher volume.^{14,15}

Several studies have concluded that direct supervision increases squat and bench press strength.^{1,27,28} For example, 12 weeks of a periodic resistance training program under a highly motivated male strength trainer's supervision compared with an unsupervised environment resulted in significant strength gain in both the squat and bench press.²⁷ In this study, the level of supervision enhanced the

subject's motivation compared with the control group, possibly resulting in an increase in strength.

The present study clearly demonstrated that the number of repetitions and volume significantly increased, and this might be the result of a motivational increase due to the coach's encouragement and the instantaneous feedback from the VBT device. Some studies have confirmed that either a coach's verbal encouragement²⁹ or instantaneous velocity feedback may improve motivation and competitiveness during resistance training, but these studies only measured power, force, and velocity, not the volume or workload. Nonetheless, it is safe to assume that the higher force and velocity values under the same load and repetition will certainly increase the number of repetitions before failure³⁰ because the velocity of the last repetition is almost close to 1RM velocity as long as the subject did their best effort.⁵ A combination of the bar velocity measurement and subjective questionnaire analysis study conducted by Weakley et al. supports this idea that the almost certain differences were observed in motivation and competitiveness, so the perceived workload is significantly greater when visual feedback was provided in the study group.²⁸ Accordingly, we propose that both encouragement from a coach and instantaneous external feedback from a VBT device may help athletes to increase their motivation, which leads to a greater number of repetitions and volume for relatively light loads (65% 1RM). In the periodization concept, it could be effectively applied for developing muscular endurance and hypertrophy because it stimulates a greater adaptation for the training purposes.

However, it is apparent that only the VBT group showed a statistically greater difference when the load intensity was increased to 85% 1RM (NSUP: 527±92.12 kg, CSUP: 743.50±107.29 kg, VBT: 972.75±163.75 kg, respectively). The exercise volume was approximately doubled when training under VBT technology (+84.58% vs. NSUP) compared with the

CSUP group (+40.83% vs. NSUP). As volume only includes sets and loads per repetition, we considered these as quantity factors, but total work is a slightly different concept, in between quantity and quality, because it consists of not only reps and loads, but also includes kinematic factors like force and distance. Total work was only significantly greater in the VBT group.

Slightly higher peak force outputs at both intensities may contribute to the maximum workload when comparing the NSUP and CSUP groups. Interestingly, while peak force varied slightly between groups in each trial, peak power and peak velocity were significantly greater only in the VBT group compared with the NSUP and CSUP groups (peak power: vs. NSUP, $p<0.06$, vs. CSUP, $p<0.015$; peak velocity: vs. NSUP, $p<0.07$, vs. CSUP, $p<0.023$, respectively). These data obviously indicate that velocity, not force, significantly influences power output because without bar movement, power cannot be calculated while the velocity remains zero. In addition, as force equals mass times acceleration and as the mass was constant for the same intensity, only acceleration affected the force output within trials. Although there was a slightly higher peak force production in the VBT group, no statistical significance was found in either the 65% 1RM or the 85% 1RM trials. It is assumed that the instantaneous velocity feedback stimulated acceleration because the peak velocity for the VBT group was significantly greater than either the NSUP or CSUP groups, thereby increasing the peak power.^{1,28} The finding that the level of encouragement and knowledge provided by the coach significantly affects the training outcome may be the most important result of this study. For example, in this study, the investigator did not specifically encourage the coach to require subjects to perform powerful and explosive movements, but only mentioned that all subjects should reach failure using their maximum effort. Training style in the CSUP group was therefore totally controlled by the coach. Many studies

confirm that movement velocity during resistance training will affect neuromuscular adaptation.^{16,17} Intentionally explosive movement is the key to increasing type IIx muscle fibers, with a corresponding increase in force development.¹⁸ However, training outcomes will not be promising without proper supervision.^{19,20}

This study was conducted to determine if a VBT device helps athletes to concentrate on their resistance training program in a team setting, where no CSCSs are available. Strength and conditioning specialists are not common in South Korea, so not many teams hire CSCSs. Therefore, the technical coach's supervision is often easily observable.^{6,31} However, the effectiveness of the resistance training session is dependent on the knowledge of the coach as previously mentioned.⁷ As the CSUP group only showed increased repetitions and volume, the coach's knowledge may be limited to and/or focused on the quantity measurement, rather than the quality, of each movement. Studies have shown that physical educators and sports coaches have a very limited knowledge of safe and effective resistance training techniques.³¹ It has also been pointed out that only 8.4% of sport coaches and physical educators have resistance training-related certificates.⁶ This may help readers understand why no quality factor differences were observed in the present study when comparing the CSUP and NSUP groups.

Conversely, a clear visual and audible notification combined with a preset 1RM mean velocity score on a screen, strongly motivated athletes to increase movement velocity and elicited a greater peak power output regardless of intensity compared with both groups. An instantaneous kinematic feedback therefore is the true benefit of velocity-based training. Numerous studies showed that instantaneous visual feedback from various VBT devices increased bar velocity and power output.^{1,28} One study directly measured the bar velocity in 65% 1RM loads and showed that

the peak concentric velocity of the control group (with no feedback) was very similar to the present NSUP and CSUP groups (0.65 ± 0.05 m/s vs. 0.67 ± 0.05 m/s vs. 0.64 ± 0.05 m/s), but the peak velocity of the feedback group was significantly greater than the control group in the previous study (0.65 ± 0.05 m/s vs. 0.70 ± 0.04 m/s). Although this velocity is still much slower than the VBT group in the present study, this might be due to an age and population difference as the previous study subjects were subelite adolescent rugby players (age: 17.1 ± 0.5 years), which is younger than the present study (age: 17.1 ± 0.5 years), so they may not be as strong.²⁸

In this study, while repetitions and volume were significantly greater in both the CSUP and VBT groups, peak power, peak velocity, and total work were identically greater in the VBT group compared with all other groups and trials. A limitation of the present study is that a single study cannot include all parameters, so further research should be conducted to investigate the level of resistance training knowledge of coaches compared with the effectiveness of VBTs. In addition, a combination of encouragement from a coach with kinematic information from a VBT device may compensate for a lack of training knowledge, so the comparison would be very interesting.

This study indicated that the level of a coach's experience and knowledge will significantly affect training efficiency in terms of quantity and quality, but the velocity-based training may only be effective when the athletes' lifting technique is nearly perfect as it maximizes movement velocity, so poor lifting techniques may increase the risk of injuries in the weight training room.

CONCLUSION

The present study, therefore, concluded that the instantaneous feedback from VBT device encouraged wrestling athletes to perform longer and harder than coach's encouragement in the resistance training. This may suggest that velocity-based training

effectively assisted resistance training session even if strength coach or team coach is not available.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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